Final Report for the Minnesota County Roadway Safety Plans

Prepared for

Minnesota Department of Transportation

January 2014

CH2MHILL

Contents

Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ATP	Area Transportation Partnership
CRF	crash reduction factor
FHWA	Federal Highway Administration
GIS	geographic information system
HSIP	Highway Safety Improvement Program
MnCMAT	Minnesota Crash Mapping and Analysis Tool
MnDOT	Minnesota Department of Transportation
mph	miles per hour
NCHRP	National Cooperative Highway Research Program
RSA	Road Safety Assessment
SHSP	Strategic Highway Safety Plan

Introduction / Overview

In the state's 2008 Strategic Highway Safety Plan (SHSP), the Minnesota Department of Transportation (MnDOT) committed to increasing the level of engagement of local highway agencies in the statewide safety planning process. This was the genesis of MnDOT's County Roadway Safety Plans project. This commitment was a reflection of two key facts:

- Approximately 50 percent of severe crashes (those crashes that result in at least one fatality or incapacitating injury) in Minnesota occur on local roadways.
- Minnesota has almost 140,000 miles of roadways and local agencies are responsible for more than 90 percent of these miles.

The initial outreach efforts for the project involved providing funding support for Road Safety Assessments (RSAs) on local road systems. Approximately 20 counties took advantage of this funding and had the assessments performed on a sample of their road systems. An evaluation of these assessments found that some valuable information was documented. This information included insight about how horizontal curves may contribute to crashes on rural roadways, and the identification of how guide signs along major roads caused sight restrictions for vehicles on the minor approaches (which resulted in a new sign layout that moved the guide signs away from the line of sight). However, it was also determined that the results of the assessments may not be reliable because the technique for selecting intersections and roadway segments for analysis was likely biased – they were selected by the local systems engineer based on a variety of subjective considerations, such as public complaints/concerns, a notable crash in the past, a recent severe crash, etc.

MnDOT's support for the RSA initiative as a tool to generate projects for the statewide safety program was stopped because of concerns about the technical quality of the results and because the RSAs did not regularly lead to implementation. (Note: MnDOT still supports conducting RSAs at a few specific locations where it has been determined that safety concerns would benefit from an independent assessment.) Following the completion of the RSAs, feedback from the local systems engineers found that they were unfamiliar with the process of conducting system-wide safety assessments and with developing safety projects. They were familiar with developing reconstruction projects but had limited history of participating in the MnDOT's Highway Safety Improvement Program (HSIP) process and were reluctant to use their own funds to implement the suggested safety improvements.

MnDOT's next effort to engage local systems engineers focused on revising the selection criteria for funding projects through the HSIP. Historically, the HSIP was entirely a reactive program where the basic criteria for selecting projects for funding included providing proof that the location was a high-crash location and where the benefits of implementation exceeded the cost of implementation. This approach directed most funding to projects at "black spots" (locations with an abnormally high number of crashes), most of which are in the Minneapolis-St. Paul metropolitan area (where approximately 70 percent of all crashes in Minnesota occur), on state highways, and at signalized intersections along high-volume arterials. However, these characteristics were not consistent with the safety priorities documented in the SHSP.

As stated in the SHSP, Minnesota is focused on reducing severe crashes statewide. Severe crashes are overrepresented in rural areas (70 percent of severe crashes) and on local road systems (50 percent of severe crashes), and most commonly involve a single vehicle running off a rural road (with over 50 percent of these crashes occurring in a horizontal curve). It was also noted that even though these are the most common types of severe crashes, the density of these crashes is approximately 0.002 severe crashes per mile per year and the expectation was that very few locations would actually average one severe crash per year.

In order to address these characteristics, MnDOT added a systemic component to the HSIP (to complement the locations identified through the traditional site-analysis methodology) that did not require high crash numbers. Funding would be directed towards implementing select/priority low-cost safety strategies along roads considered to be at-risk based primarily on the presence of roadway and traffic characteristics associated with locations with similar severe crashes (typically, rural, high-speed, low-volume roads on the local system). Following the revisions to the HSIP process, MnDOT held workshops around the state to help local system engineers become familiar and comfortable with the new project development and HSIP application process. These workshops emphasized the fact that approximately 50 percent of HSIP funds would be dedicated to projects on the local road system – projects along local roadways and outside the Minneapolis-St. Paul metropolitan area would no longer have to compete for funding against MnDOT's projects on the state system of highways.

While this initiative did have some successes, an opportunity still remained for more local roadway projects to be submitted for HSIP funding and for local projects to better focus on high-priority, low-cost safety strategies. Follow-up conversations with a number of county engineers determined that even though they had a great deal of experience developing and implementing reconstruction and maintenance projects, they were generally unfamiliar with safety analysis techniques and safety project development. Few had undertaken a systemic risk assessment of their road system, identified priority crash types, linked these crashes to effective low-cost safety strategies, identified candidate locations for safety strategy implementation, nor submitted applications for HSIP funding.

With this feedback, MnDOT, with the assistance of Minnesota's county engineers and the Federal Highway Administration (FHWA), developed the basic outline of a program to achieve the desired level of engagement with local highway agencies. In addition to continuing to dedicate HSIP funding to local road systems, MnDOT would provide the technical assistance to every county in Minnesota to prepare a Roadway Safety Plan. Preparing these Roadway Safety Plans would answer three fundamental questions that are key to developing safety projects for the HSIP: (1) what are the priority crash types; (2) what are the priority safety strategies; and (3) what are the priority locations where projects should be implemented. The specific steps in the process include (Figure 1-1):

1. Analyze crash data to identify regional and county-specific safety emphasis areas – the types of crashes that represent the greatest opportunity for reduction
2. Identify a comprehensive list of safety strategies and convene a workshop to identify a short list of safety strategies that have a demonstrated effectiveness to reduce the priority crash types
3. Conduct a system-wide risk assessment to identify the high-priority candidate locations for safety investment
4. Develop safety projects – the deployment of a specific strategy at a specific location that was determined to be a high-priority candidate for safety investment

Consistent with the guidance from the FHWA regarding state SHSPs, these County Roadway Safety Plans are data-driven, include participation by a variety of safety partners, and are comprehensive in nature – they address both infrastructure- and driver-behavior safety issues. The primary purpose of these plans was to document for each county the outcome of the following three-step prioritization exercise:

1. Identify the types of crashes that represent the greatest opportunity for reduction
2. Screen the safety strategies that would be most effective at reducing those types of crashes
3. Identify the locations along each county's road system that are the highest-priority candidates for safety investment

Given the level of effort required to conduct the technical analysis of each county's road system, the need to maintain a high level of coordination with each county's engineer combined with the fact that there are 87 counties in Minnesota, the process of developing the plans was divided into four 9-month-long phases beginning in November 2009. The selection of the counties to participate in each phase was made by MnDOT staff using fatal crash rates and existing Area Transportation Partnerships (ATPs) boundaries. The counties participating in each phase are illustrated in Figure 1-2. The ATPs are summarized as follows:

FIGURE 1-1
Minnesota County Road Safety Planning Process

- Phase I – ATP 3 (North Central) and ATP 6 (Southeast)
- Phase II – ATP 4 (West Central), ATP 8 (Southwest), and Hennepin County
- Phase III – ATP 1 (Northeast – including Chisago County) and ATP 7 (South)
- Phase IV – ATP 2(Northwest) and ATP Metro (Twin Cities Region)

A key element of the approach to preparing the safety plans was the use of a systemic risk assessment process. The rationale for the use of a systemic risk assessment was the expectation that there would be few or no high-crash locations on rural county roadways, which in fact proved to be true. After reviewing almost 22,000 miles of paved county highway, 20,000 curves, and 13,000 intersections, only 18 locations were found to have multiple severe crashes and all averaged less than one severe crash per year. In addition, even though severe crashes are scattered across many miles, curves, and intersections, it was assumed that they are not uniformly scattered – not every location along the county system is equally at risk for a severe crash. The project team developed a new approach using crash surrogates – roadway and traffic characteristics that would stand in for crash data – to identify the most at-risk locations across each county's road system that became the priority candidates for safety investments.

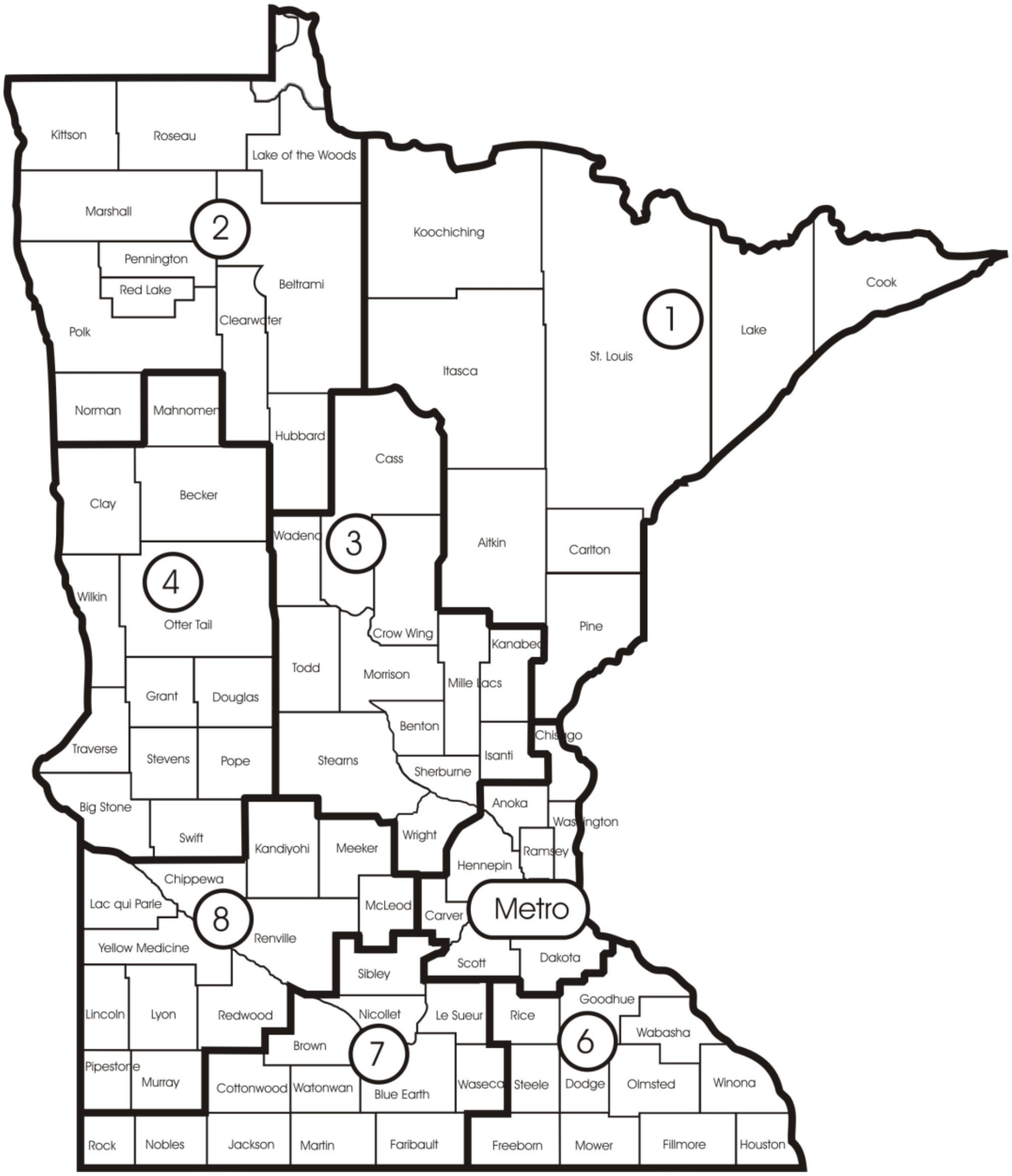


FIGURE 1-2
Minnesota's Area Transportation Partnerships

It was the intent of this effort to provide each county with a list of projects that are consistent with the statewide priorities established in the SHSP and that can be proactively deployed across their system. These projects are considered to supplement any efforts on the counties part to develop reactive safety projects at high-crash locations using site analysis techniques. Delivery of the County Roadway Safety Plans began in 2010 and the final six County Roadway Safety Plans were delivered in September 2013.

Crash Data Analysis and Safety Emphasis Areas

The first step in the prioritization process was to identify the types of crashes that represent the greatest opportunity for reduction. The technical analysis documented the number, distribution, and characteristics of severe crashes in each county, ATP, and for all of Greater Minnesota (the area of the state outside of the 7-county Minneapolis-St. Paul metropolitan area). Identifying the types of crashes that are overrepresented helps in the screening of potential safety strategies. In most cases, safety strategies are linked to specific crash types and understanding characteristics of the crashes helps in identifying candidate locations for safety investment.

The primary source of the crash data used in the analysis was the Minnesota Crash Mapping and Analysis Tool (MnCMAT). A secondary data source was the Minnesota Department of Public Safety's records, which were used to provide more complete information about the driver behavior characteristics associated with the severe crashes (safety belt usage, driver condition, etc.). In all of the analytical efforts, 5 years of data were used but because the project spanned all or part of 4 calendar years, data from the most recent year were added as soon as it became available. As a result, the first Phase of the project used crash data from 2005 through 2009 and the last Phase used data from 2007 through 2011.

The initial effort involved disaggregating the crash data into basic categories: Drivers, Special Users, Vehicles, Highways, Emergency Medical Services, and Management. The American Association of State Highway and Transportation Officials' (AASHTO's) 22 safety emphasis areas are divided amongst these categories. The use of AASHTO's safety emphasis areas accomplishes two desirable outcomes:

- Provides insight as to what types of crashes represent the highest priority. The greatest opportunity for reduction is assumed to be associated with large numbers of crashes.
- Begin the prioritization process for safety strategies. Safety strategies are associated with and intended to mitigate specific types of crashes. Therefore, as particular safety emphasis areas are dropped from consideration (due to low numbers of crashes), their unique set of strategies can also be dropped from consideration.

Using the latest five years of crash records (2007-2011), the results of this analysis (Table 2-1) indicate the following priority list of safety emphasis areas:

- Greater Minnesota (80 counties)
    - Aggressive Driving and Speeding-Related
    - Drug and Alcohol-Related
    - Unbelted Vehicle Occupants
    - Road Departure Crashes
    - Intersection Crashes
- Metropolitan Area (7 counties)
    - Young Drivers
    - Drug and Alcohol-Related
    - Inattentive Drivers
    - Intersections Crashes
    - Head-On Crashes

TABLE 2-1
Minnesota's Priority Safety Emphasis Areas

Emphasis Area		Statewide Percentage	Greater Minnesota: Interstate, US & TH	Greater Minnesota: CSAH & CR	Greater Minnesota: City, Twnshp & Other	Metro: Interstate, US & TH	Metro: CSAH & CR	Metro: City, Twnshp & Other
	Total Fatal and Serious Injury Crashes	19,648	5121	5037	2232	2220	2928	2126
Drivers	**Young drivers (under 21)**	**8%**	7% (355)	8% (380)	10% (227)	7% (157)	**9% (277)**	9% (194)
	Unlicensed drivers	3%	3% (151)	2% (125)	3% (67)	4% (80)	3% (85)	4% (82)
	Older drivers (over 64)	5%	7% (369)	5% (244)	4% (90)	4% (96)	5% (145)	4% (89)
	Aggressive driving and speeding-related	7%	7% (365)	**8% (390)**	9% (192)	8% (187)	5% (161)	8% (162)
	Drug and alcohol-related	**10%**	8% (423)	**13% (634)**	11% (250)	10% (230)	**8% (221)**	9% (192)
	Inattentive, distracted, asleep drivers	7%	9% (445)	6% (308)	5% (120)	8% (176)	**8% (226)**	5% (110)
	Safety awareness	- -	- -	- -	- -	- -	- -	- -
	Unbelted vehicle occupants	**9%**	11% (538)	**12% (591)**	10% (230)	8% (188)	6% (163)	5% (107)
Special Users	Pedestrians crashes	3%	2% (85)	1% (66)	4% (98)	4% (85)	5% (149)	8% (169)
	Bicycle crashes	2%	1% (32)	1% (40)	3% (70)	1% (16)	3% (86)	4% (92)
Vehicles	Motorcycles crashes	6%	5% (259)	7% (369)	5% (112)	6% (132)	7% (195)	7% (140)
	Heavy vehicle crashes	4%	7% (333)	3% (138)	2% (46)	5% (105)	3% (86)	3% (54)
	Safety enhancements	- -	- -	- -	- -	- -	- -	- -
Highways	Train-vehicle collisions	1%	1% (36)	2% (82)	1% (25)	1% (32)	1% (29)	1% (22)
	Road departure crashes	**11%**	11% (579)	**16% (825)**	11% (247)	9% (191)	6% (172)	6% (122)
	Consequences of leaving road	- -	- -	- -	- -	- -	- -	- -
	Intersection crashes	**16%**	15% (745)	**12% (582)**	15% (343)	17% (379)	**24% (707)**	21% (445)
	Head-On and Sideswipe (opposite) crashes	6%	7% (373)	5% (249)	5% (110)	6% (127)	**7% (209)**	6% (134)
	Work zone crashes	1%	1% (33)	0% (14)	0% (5)	2% (39)	1% (17)	1% (12)
EMS	Enhancing Emergency Capabilities	- -	- -	- -	- -	- -	- -	- -
Management	Information and decision support systems	- -	- -	- -	- -	- -	- -	- -
	More effective processes	- -	- -	- -	- -	- -	- -	- -

Source: 2007-2011 Minnesota Crash Records

It should be noted that the top 5 safety emphasis areas—based on number of severe crashes—identified for the county roads in Greater Minnesota differ from the statewide priorities by dropping young drivers and adding aggressive driving and speeding-related. In the Metro area, further analysis found that pedestrian and bicycle crashes were concentrated at urban signalized intersections. So while pedestrian and bicycle crashes was not selected as a top safety emphasis area in order to address all related severe crashes, it became a focus through the intersection safety emphasis area. The priorities for the Metropolitan Area counties are also similar to the statewide priorities, with the following exceptions: unbelted vehicle occupants and road-departure crashes are not included on the list, and inattentive drivers and head-on crashes are added.

Each County Roadway Safety Plan also included a similar table documenting the distribution of severe crashes among the emphasis areas based on the total number of crashes in the particular ATP and for the individual county. This information was provided as proof that the identified crash type priorities based on the larger ATP data set still appeared to be valid at the county level, even though the county data sets contained far fewer crashes and were therefore somewhat less reliable. In all cases, there was a very high level of consistency among the statewide, ATP, and individual county data sets.

The second step focused on the highway-related crashes and disaggregating the crashes by system (state versus county versus city), location (rural versus urban), roadway segment versus intersection, and by type of crash (using crash diagram from the crash report). As with the safety emphasis areas, the state was divided into Greater Minnesota and the Metropolitan Area because of the expectation that the indicated priorities would be different. The results of this analysis are documented in crash trees (Figure 2-1 for Greater Minnesota and Figure 2-2 for the Metropolitan Area). Key conclusions include:

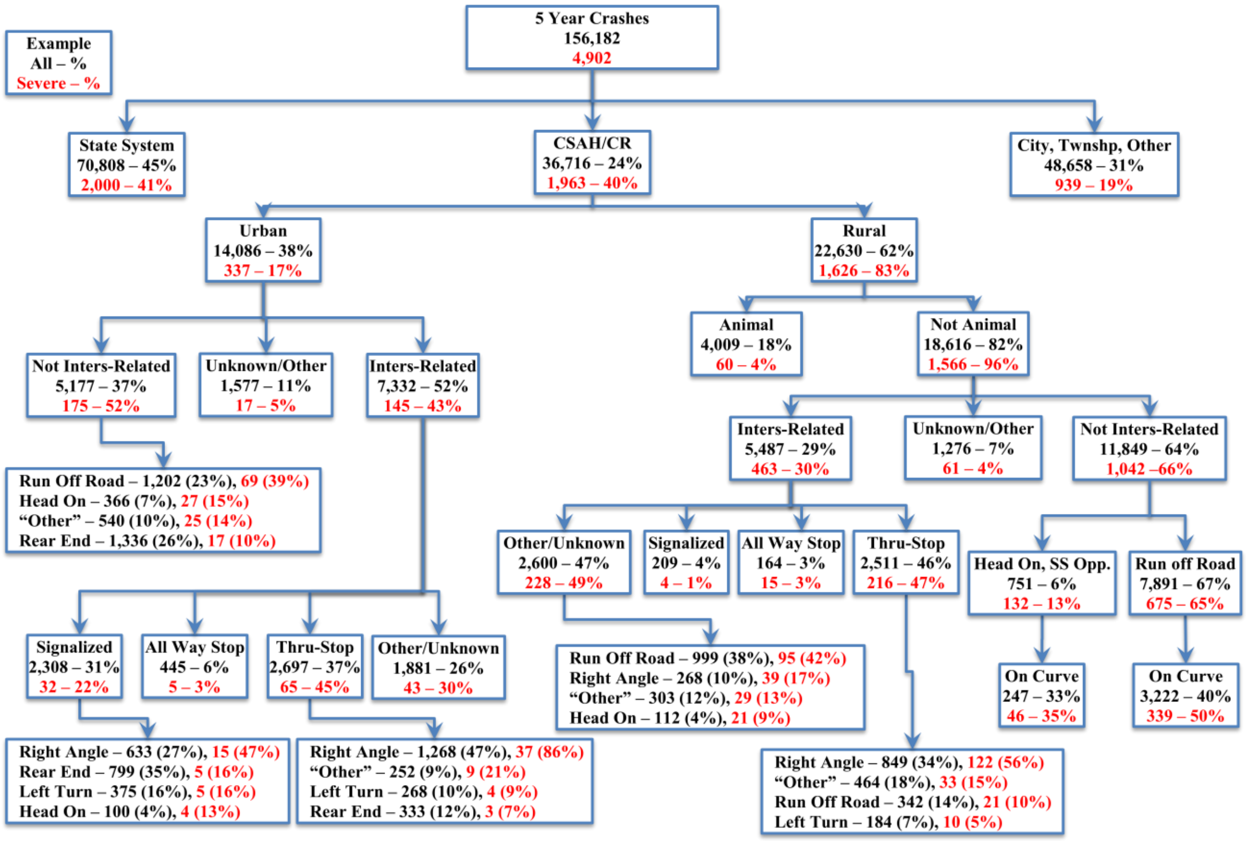


FIGURE 2-1
Greater Minnesota Crash Tree

Source: 2007-2011 Minnesota Crash Records

Greater Minnesota

- There was an almost equal distribution of severe crashes between the state and county road systems (2,000 severe crashes on the state road system versus 1,963 crashes on the county road system).
- On the county road system, 83 percent of severe crashes are considered to be rural (no city code assigned to the crash).
- Crashes with animals (mostly deer) account for 4 percent of severe crashes. This suggests that animal crashes are not a priority. [Note: Except in the cases where the driver or a passenger is injured, animal crashes are under reported.]
- Approximately two-thirds of the rural crashes are not intersection related and approximately two-thirds of these involve a single-vehicle, road-departure crash.
- One-half of all of the severe road-departure crashes occurred in a horizontal curve.
- Approximately one-third of the rural crashes were intersection related, almost one-half of these occurred at Thru-STOP-controlled intersections and over one-half of these involved a right-angle crash.

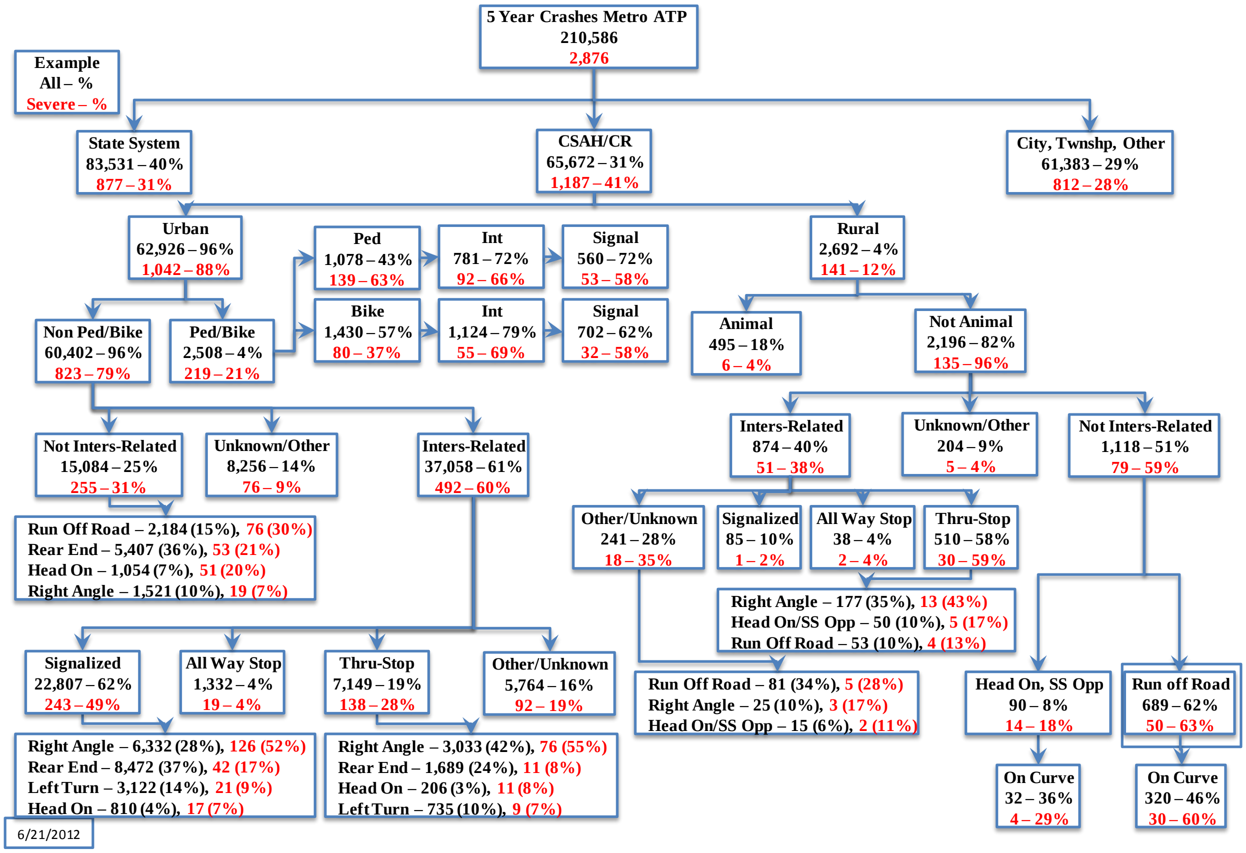


FIGURE 2-2
Twin Cities Metropolitan Area Crash Tree

Source: 2007-2011 Minnesota Crash Records, including Anoka, Carver, Dakota, Hennepin, Ramsey, Scott and Washington counties.

Metropolitan Area

- In the Metropolitan Area, there are more severe crashes on the county road system than on either the state or city road systems.
- On the county road system, 87 percent of severe crashes are considered to be urban (a city code was assigned to the crash).
- Approximately two-thirds of the urban crashes are intersection related, and the most common types were right-angle and pedestrian/bicycle crashes. The majority of both types of crashes occurred at intersections with traffic signal control.
- Approximately one-third of the urban crashes are not intersection related and the most common types were rear-end and head-on crashes.

As was the case with the distribution of severe crashes by safety emphasis area, each County Roadway Safety Plan also contained crash trees for the ATP and the individual county. The development of the Roadway Safety Plans relied heavily on the crash tree for the ATP because of the credibility provided by having more than 100 severe crashes in the data set. (In fact, all regions except ATP 2 had more than 200 severe crashes in their data set.) The priorities indicated in the crash trees (that is, rural roads, road departure crashes, and the over-involvement of curves) were ultimately reflected in the safety projects that were identified. In almost all cases, there was a high level of consistency in the priorities indicated by the state, regional (ATP), and individual county crash trees.

This second level of analysis also produced two additional key points. First is proof that on rural county systems, safety investment should be focused on the paved roads. The data is very compelling:

- 94 percent of severe crashes on the rural county system occurred on paved roads, which make up only 69 percent of the rural county system mileage studied (Table 2-2)
- The density of severe road-departure crashes on the county system is ten times higher on paved roads than on gravel roads
- Only one county in Minnesota averages one fatal crash per year on their gravel roads (almost one-half of Minnesota counties had no fatal crashes on their gravel roads over a 5-year study period)

TABLE 2-2
Minnesota's Rural County Highway System*

	All Roads	Paved Roads	Gravel Roads**
County Road Network			
Miles	38,430	26,600	11,830
Annual VMT *(in millions)*	7,111	6,818	293
All Severe Crashes			
Severe Crashes***	2,409	2276	133
Annual Severe Crashes	482	455	27
Severe Crash Density *(severe crashes per mile per year)*	0.01	0.02	0.002
Severe Road Departure Crashes			
Severe Road Departure Crashes***	1,024	963	61
Annual Severe Road Departure Crashes	205	193	12
Severe Road Departure Crash Density *(severe road departure crashes per mile per year)*	0.01	0.01	0.001

** Source: Based on the study network for the Minnesota County Road Safety Plan.*

*** Note: In Phase I, only select county gravel roads were included in the study.*

**** Note: Crash data years varied by phase, including 2005-2009 for Phase I and 2007-2011 for Phase IV.*

The second key point indicates that increasing the level of engagement of the counties in the statewide safety planning effort is a priority. The Greater Minnesota and the Metropolitan Area crash trees (Figures 2-1 and 2-2) indicate that there are more severe crashes on the county road system than on the state's road system and the number of severe crashes per year (660 severe crashes) is significant and represents a substantial opportunity for reduction as a result of targeted safety investments. However, the only safety engineers with easy access and an assigned responsibility to consider this kind of information are MnDOT staff in the Office of Traffic, Safety and Technology. In Greater Minnesota, the counties average fewer than five severe crashes per year on their road system and seven of the eleven counties in ATP 2 average a single severe crash per year on their road system. With this kind of information, it is easy to understand that the perceived priority of safety on the county system could be very different depending on the view of the crash tree - from the top down or from the bottom up.

The third step in the prioritization process of the statewide data set documented the trend lines for the priority highway-related safety emphasis areas (Figures 2-3, 2-4, 2-5, 2-6 and 2-7) to see if any new insights were suggested. The results of this effort confirmed the importance of addressing safety on the local road system in Minnesota – in all but one case (severe head-on crashes – part of the Road-Departure safety emphasis area), more severe crashes occurred on the local road system than on the state's system of trunk highways.

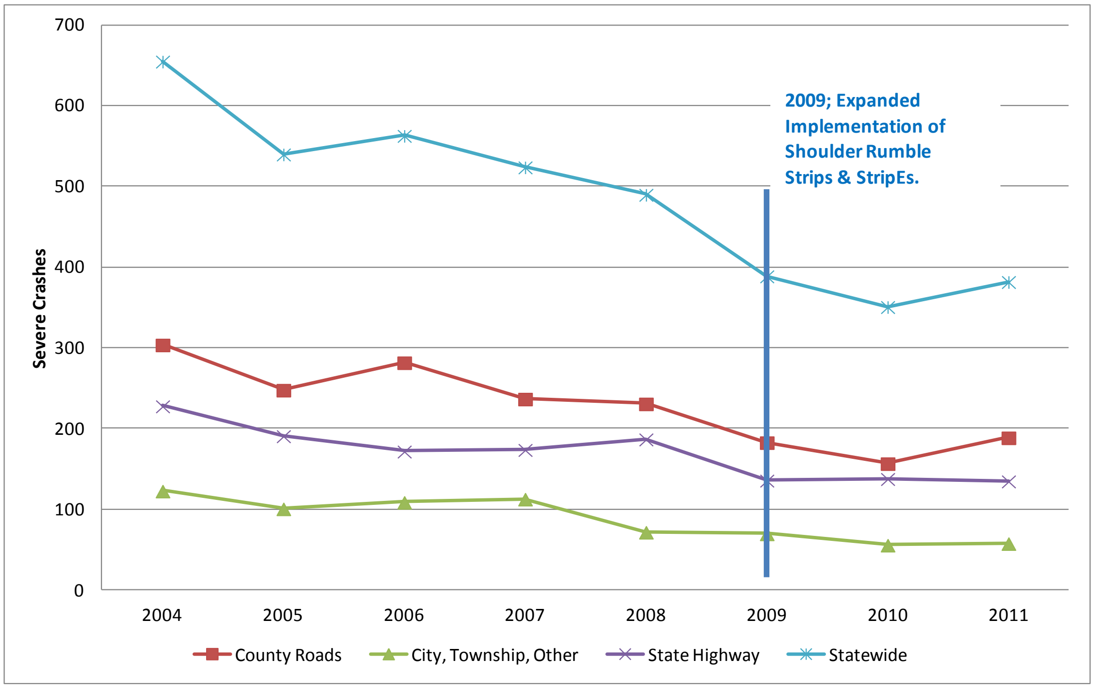


FIGURE 2-3
Severe Single Vehicle Road Departure Crashes

Source: 2004-2011 Minnesota Crash Records

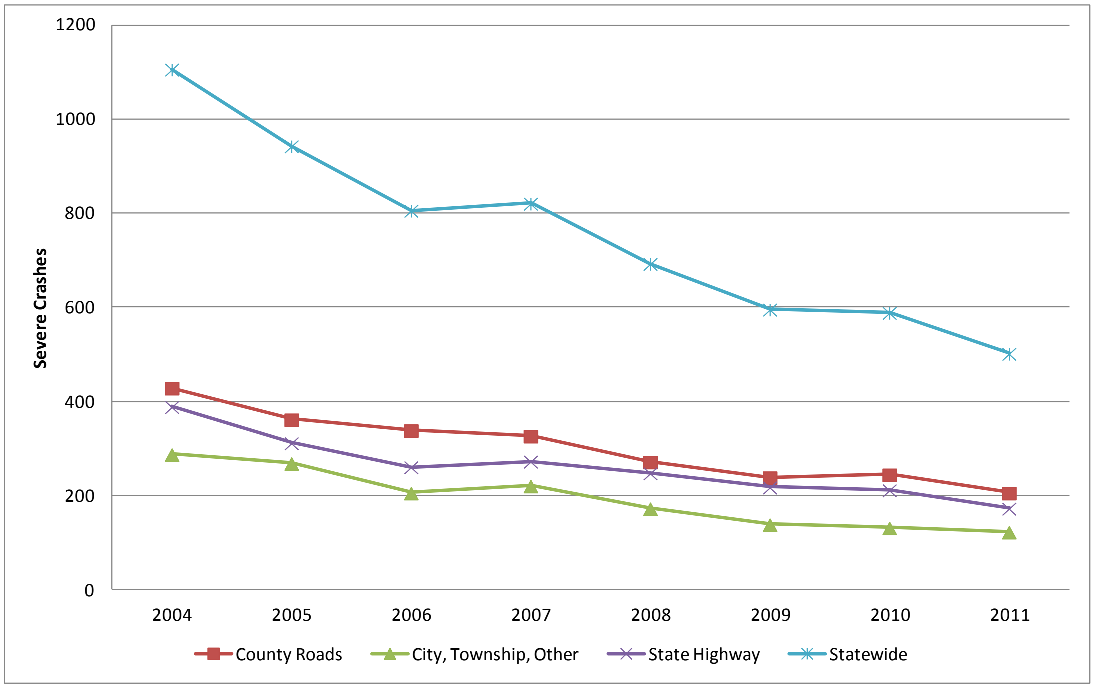


FIGURE 2-4
Severe Intersection Crashes

Source: 2004-2011 Minnesota Crash Records

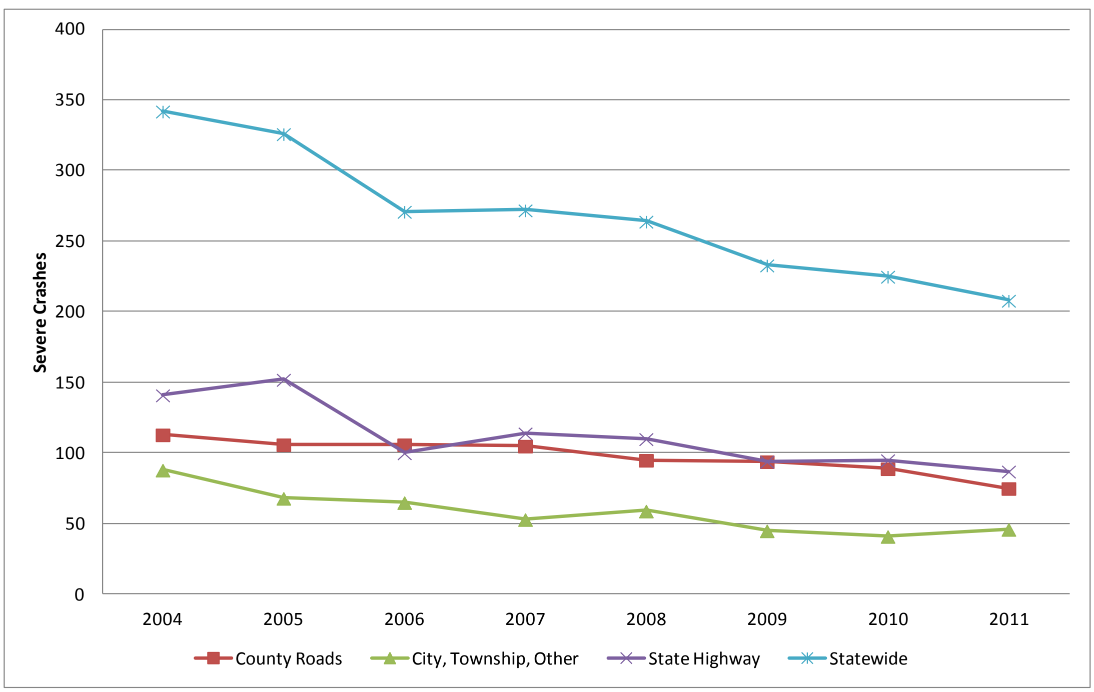


FIGURE 2-5
Severe Head-On and Across Median Crashes

Source: 2004-2011 Minnesota Crash Records

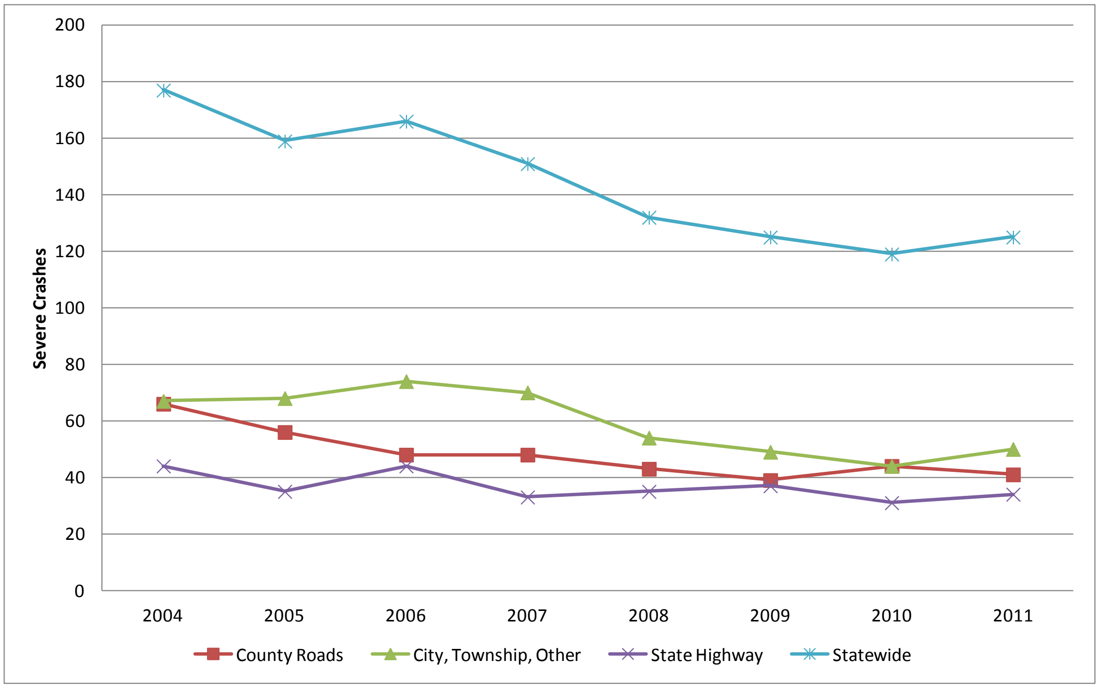


FIGURE 2-6
Severe Pedestrian Crashes

Source: 2004-2011 Minnesota Crash Records

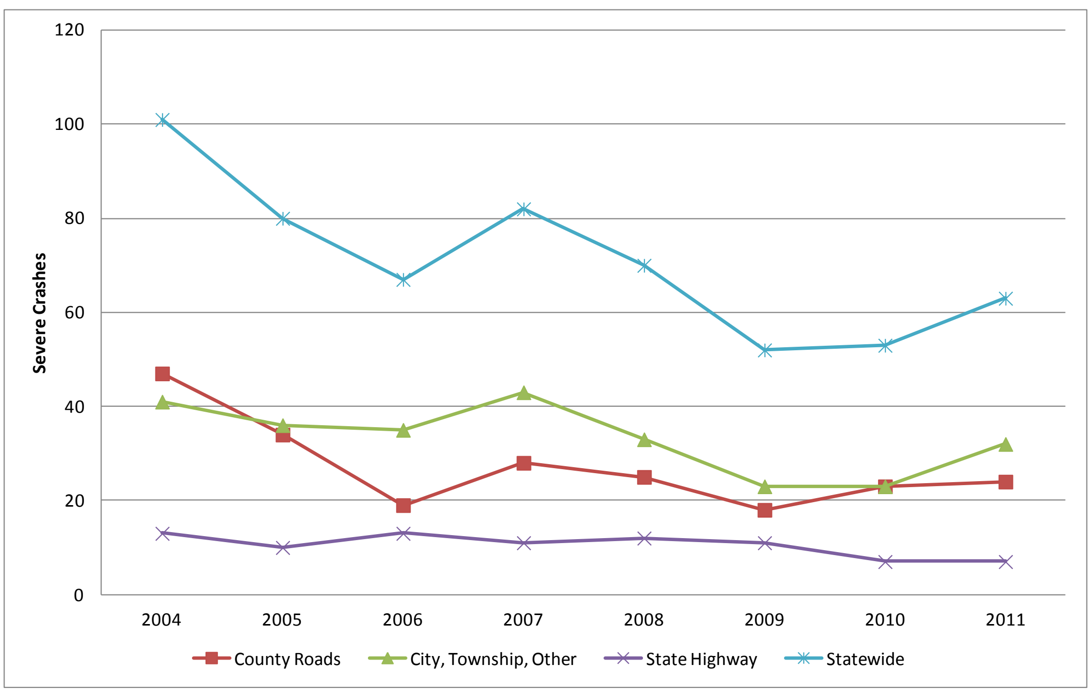


FIGURE 2-7
Severe Bicycle Crashes

Source: 2004-2011 Minnesota Crash Records

The result of the crash analysis was identifying the crash types that represent the greatest opportunity for reduction in both Greater Minnesota and the 7-county Minneapolis-St. Paul metropolitan area. These crash types then became the focus for the individual County Roadway Safety Plans:

- **Priority crash types – Greater Minnesota counties**
  - Lane-departure crashes(run off road and head-on) along rural roadway segments
  - Curve-related crashes along rural roadway segments
  - Angle crashes at rural intersections
- **Priority crash types – Metropolitan Area counties**
  - Rural areas – same as in Greater Minnesota
  - Right-angle crashes at urban signalized intersections
  - Pedestrian/bicycle crashes at urban intersections
  - Rear-end crashes along urban roadway segments

Safety Strategies

The second key component of the County Roadway Safety Plans is identifying a short list of safety strategies that would be implemented to address the priority crash types. A list of potential safety strategies was assembled from the published safety research, primarily the NCHRP *Report 500* Series, *Countermeasures that Work* (focusing on driver behavior), and FHWA's Crash Modification Factor Clearing House. This effort identified over 600 possible strategies. Using the priority crash types as selection criteria, MnDOT staff reduced this list – most safety strategies are associated with the mitigation of a particular crash type, for example, road edge enhancements to reduce the number of severe road departure crashes along rural roadways.

The next level of screening focused on the general effectiveness and basic implementation costs of the remaining safety strategies. Initially the strategies were identified as being proven, tried, or experimental. The definition of these terms was borrowed from the NCHRP *Report 500* Series:

- **Proven –** Proven effective strategies have been widely deployed and have been subject to academically rigorous statistical evaluations and the results are all in a fairly narrow range. Examples of proven strategies are edge rumble strips, enhanced curve delineation, streetlights at rural intersections, pedestrian refuge islands, and managing access/conflicts along urban arterials.
- **Tried –** Tried strategies have not been as widely deployed, lack the rigorous statistical evaluations, or the results of the evaluations have not been consistent with evaluations (sometimes showing a decrease in crashes and other times an increase in crashes). Examples of tried strategies are transverse rumble strips (on the approaches to rural intersections), marked pedestrian crosswalks, and indirect turn treatments (J-turns).
- **Experimental –** Experimental strategies are typically relatively new, often involving technologies that are just beginning to be deployed and that are lacking sufficient deployment and rigorous statistical evaluation. Examples of experimental strategies are dynamic warning signs (at intersections and horizontal curves), dynamic Deer Crossing signs, and dynamic pedestrian crossing treatments.

There is currently no requirement at either the federal or state level that safety funds must be directed to only those projects that implement proven safety strategies. However, there is a bias among safety program managers toward projects that use the proven strategies because that provides the highest level of confidence that those projects will result in crash reductions similar to what has been achieved elsewhere. This level of screening also documented the basic range of implementation costs – low, medium, or high. Unique thresholds were developed for the County Roadway Safety Plans because participants in the workshops asked for definitions that were more definitive and actual dollar values (which are not provided in the NCHRP *Report 500* Series). The thresholds adopted for the Safety Plans are as follows:

- Low-cost – Strategies that cost less $10,000 per mile or per intersection to implement. Examples are edge rumbles, enhanced curve delineation, and rural intersection street lighting.
- Medium-cost – Strategies that cost between $10,000 and $100,000 per mile or per intersection. Examples are (narrow) shoulder paving, cable median barrier, and dynamic warning signs.

- High-cost – Strategies that cost more than $100,000 per mile or intersection to implement. Examples are reconstructing horizontal curves (increase curve radius), indirect turn intersections (on divided roadways), and roundabouts.

As was the case with effectiveness, there is no requirement to direct safety funds to low-cost projects or to have any particular mix of low-, medium- and high-cost strategies in a safety program. However, there is a bias towards use of low-cost strategies based on two documented facts about Minnesota's county roadway system: First, although more severe crashes occur on the county road system than on state highways or city streets, the density of these crashes is very low (approximately 0.01 severe crashes per mile per year). Therefore, the focus should be on implementing low-cost strategies across many miles of roadway and many intersections. And second, it was always assumed that the safety needs for 87 counties would be far greater than the amount of safety funds dedicated to the implementation of projects along the county system. Discussions with FHWA staff indicate that Minnesota is one of the top states in dedicating funds for safety projects on local roadways (approximately $15 million per year), but the final tally of high-priority safety needs for 87 counties amounted to more than $231 million. Again, the data clearly supports the need to focus on low-cost strategies to be able to spread the deployment across as many miles, curves, and intersections on the county road system as possible. The data supports overcoming the challenge of a low crash density by widely deploying proven-effective, low-cost strategies at the small fraction of high-priority locations.

The next step in the screening process involved having a facilitated discussion with safety partners from each county at the Regional Safety Workshops. More than 600 people attended the 20 workshops that were conducted in every part of the state. Lists of both infrastructure- and driver-behavior strategies (Tables 3-1 through 3-9) were presented to the stakeholders along with information about effectiveness and implementation costs. These lists of strategies had been previously screened for use in Minnesota by MnDOT staff and the project team, and represent a set of strategies considered feasible and that are primarily, but not exclusively, focused on proven effective and low-cost improvements. It is also important to note that the original decision to have multiple strategies for each of the priority crash types was in fact the better approach.

During the first phase of the project, several county engineers provided feedback that MnDOT's previous decision to only fund a single strategy (such as edge rumble strips to mitigate road departure crashes) resulted in the installation of that one strategy in a few locations where it really wasn't the best solution. This action resulted in negative public comments and, in a few cases, a second project had to be undertaken by the counties to basically undo what had just been done. These negative situations were regularly brought up during the facilitated discussions at the workshops. The response was to point to the other potential safety strategies and talk about the application of the right strategy at the right location.

The discussion of the strategies with the safety stakeholders included receiving their feedback regarding general observations, feasibility, challenges, and outcomes. The stakeholders were also asked to indicate their preference for the top five safety strategies that should be documented in their county's Safety Plan as priorities for implementation. The most frequently suggested strategies are as follows (with the number of times the strategy was suggested in parentheses):

- Conduct high-visibility enforcement campaigns for distracted driving, seat belt use, speeding, driving while impaired, and graduated driver's license restrictions (a range of 239 votes for distracted riving up to 433 votes for seat belt use)
- Install edge rumble strips (152 votes for edge line rumble strips and 278 votes for shoulder rumble strips)

- Enhanced delineation for horizontal curves (285 votes)
- Provide street lighting at rural intersections (226 votes)
- Supplement conventional enforcement of red-light running with confirmation lights (213 votes)

TABLE 3-1
Infrastructure Strategies Addressing Intersection Crashes at Unsignalized Intersections Considered at Safety Workshops

Objectives	Strategies	Relative Cost to Implement and Operate	Effectiveness	Typical Timeframe for Implementation
A Reduce the frequency and severity of intersection conflicts through geometric design improvements	A1 -- Restrict or eliminate turning maneuvers by providing channelization or closing median openings	Low	Tried	Short
	A2 -- Realign intersection approaches to reduce or eliminate intersection skew	High	Proven	Medium
B Improve sight distance at unsignalized intersections	B1 -- Clear sight triangle on approaches and in medians by clearing grub, eliminating parking, etc	Low	Tried	Short
	B2 -- Change horizontal and/or vertical alignment of approaches to provide more sight distance	High	Tried	Long
	B3 -- Eliminate parking that restricts sight distance	Low	Tried	Short
C Improve availability of gaps in traffic and assist drivers in judging gap sizes at unsignalized intersections	C1 -- Provide an automated real-time system to inform drivers of crossing conflicts and the suitability of available gaps for making turning and crossing maneuvers	Low to Moderate*	Experimental	Medium
D Improve driver awareness of intersections as viewed from the intersection approach	D1 -- Improve visibility of intersections by providing enhanced signing and delineation (stop bar, larger regulatory signs, light-emitting diode stop signs)	Low	Tried	Short
	D2 -- Improve visibility of intersections by providing lighting	Low to Moderate*	Proven	Medium
	D3 -- Install splitter islands on the minor-road approach to an intersection	Low to Moderate*	Tried	Medium
	D4 -- Provide a stop bar (or provide a wider stop bar) on minor-road approaches	Low	Tried	Short

TABLE 3-1
Infrastructure Strategies Addressing Intersection Crashes at Unsignalized Intersections Considered at Safety Workshops

Objectives	Strategies	Relative Cost to Implement and Operate	Effectiveness	Typical Timeframe for Implementation
	D5 -- Install larger regulatory and warning signs at intersections	Low	Tried	Short
	D6 -- Provide pavement markings with supplementary messages, such as STOP AHEAD	Low	Tried	Short
	D7 -- Install flashing beacons at stop-controlled intersections	Low	Tried	Short
	D8 -- Add Dynamic Warning Signs	Moderate	Tried	Short
E Choose appropriate intersection traffic control to minimize crash frequency and severity	E1 -- Provide all-way stop control at appropriate intersections	Low	Proven	Short
	E2 -- Provide roundabouts at appropriate locations	High	Proven	Long

TABLE 3-2
Infrastructure Strategies Addressing Intersection Crashes at Signalized Intersections Considered at Safety Workshops

Objectives	Strategies	Relative Cost to Implement and Operate	Effectiveness	Typical Timeframe for Implementation
A Reduce frequency and severity of intersection conflicts through traffic control and operational improvements	A1 -- Optimize clearance intervals	Low	Proven	Short
	A2 -- Employ signal coordination along a corridor or route	Low*	Proven	Medium
	A3 -- Employ emergency vehicle preemption	Moderate	Proven	Medium
	A4 -- Upgrade Signal Hardware -- 12" lenses, overhead indications, backplates	Moderate	Proven	Medium
B Improve driver awareness of intersections and signal control	B1 -- Improve visibility of intersections on approach(es)	Low	Tried	Short
	B2 -- Improve visibility of signals and signs at intersections	Low	Tried	Short
C Improve driver compliance with traffic control devices	C1 -- Supplement conventional enforcement of red-light running with Enforcement lights	Low	Tried	Short

TABLE 3-3
Infrastructure Safety Strategies Addressing Lane Departure Crashes Considered at Safety Workshops

Objectives	Strategies	Relative Cost to Implement and Operate	Effectiveness	Typical Timeframe for Implementation
A Keep vehicles from encroaching on the roadside	A1 -- Provide enhanced shoulder or delineation and marking for sharp curves	Low	Tried/Proven	Short
	A2 -- Provide enhanced pavement markings (Embedded Wet Reflective Markings)	Low	Tried	Short
	A3 -- Provide skid-resistance pavement surfaces	Moderate	Proven	Medium
	A4 -- Apply shoulder treatments *Eliminate shoulder drop-offs *Safety edge *Widen and/or pave shoulders	Moderate*	Experimental / Proven	Medium
B Minimize the likelihood of crashing into an object or overturning	B1 -- Design safer slopes and ditches to prevent rollovers	Moderate to High*	Proven	Medium
	B2 -- Remove/relocate objects in hazardous locations	Moderate to High	Proven	Medium
C Reduce the severity of the crash	C1 -- Review design of roadside hardware	Moderate to High	Tried	Medium
	C2 -- Upgrade design and application of barrier and attenuation systems	Moderate to High	Tried	Medium

TABLE 3-4
Infrastructure Strategies Addressing Head-On Crashes on Urban Roadways Considered at Safety Workshops

Objectives	Strategies	Relative Cost to Implement and Operate	Effectiveness	Typical Timeframe for Implementation
A Keep vehicles from encroaching into opposite lane	A1 -- Install centerline rumble strips for two-lane roads	Low	Tried	Short
	A2 -- Install profiled thermoplastic strips for centerlines	Low	Tried	Short
	A3 -- Provide wider cross sections on two-lane roads	Moderate to High	Experimental	Long
	A4 -- Provide center two-way left-turn lanes for four- and two-lane roads	Moderate	Tried	Short
	A5 -- Reallocate total two-lane roadway width (lane and shoulder) to include a narrow “buffer median”	Low	Tried	Medium
B Minimize the likelihood of crashing into an oncoming vehicle	B1 -- Use alternating passing lanes or four-lane sections at key locations (Swedish "2+1")	Moderate to High	Tried	Medium
	B2 -- Install cable median barriers for medians on multilane roads	Moderate	Tried	Medium

TABLE 3-5
Infrastructure Strategies Addressing Rear End Crashes on Urban Roadways Considered at Safety Workshops

Objectives	Strategies	Relative Cost to Implement and Operate	Effectiveness	Typical Timeframe for Implementation
A Improve management of access near unsignalized intersections	A1 -- Implement driveway closure/relocations	Moderate	Tried	Medium
	A2 -- Implement driveway turn restrictions	Low	Tried	Short
B Reduce the frequency and severity of intersection conflicts through geometric design improvements	B1 -- Provide left-turn lanes	Moderate	Proven	Medium
	B2 -- Provide acceleration lanes	Moderate	Tried	Medium
	B3 -- Provide right-turn lanes	Moderate	Proven	Medium
	B4 -- 4-lane to TWLT conversion	Moderate	Proven	Medium
	B5 -- Reduce speed along segment -- Dynamic Speed Feedback Sign	Low	Tried	Short

TABLE 3-6
Infrastructure Strategies Addressing Pedestrian Crashes on Urban Roadways Considered at Safety Workshops

Objectives	Strategies	Relative Cost to Implement and Operate	Effectiveness	Typical Timeframe for Implementation
A Reduce Pedestrian Exposure to Vehicular Traffic	A1 -- Provide Sidewalks/Walkways and Curb Ramps	Moderate to High	Proven	Long
	A2 -- Install or Upgrade Traffic and Pedestrian Signals	Moderate to High	Varies	Medium
	A3 -- Construct Pedestrian Refuge Islands and Raised Medians	Moderate to High	Proven	Medium
	A4 -- Provide Full/Partial Diverters & Street Closure	Moderate to High	Proven	Medium
	A5 -- Install Overpasses/Underpasses	Moderate to High	Proven	Long
	A6 -- Install Countdown Timers	Low	Tried	Medium
	A7 -- Install Advance Walk Interval	Low	Tried	Short
B Improve Sight Distance and/or Visibility Between Motor Vehicles and Pedestrians	B1 -- Provide Crosswalk Enhancements	Low	Varies	Short
	B2 -- Implement Lighting/Crosswalk Illumination Measures	Moderate to High	Proven	Medium
	B3 -- Eliminate Screening by Physical Objects	Low	Tried	Short
	B4 -- Signals to Alert Motorists That Pedestrians are crossing -- HAWK Signal	Moderate	Tried / Experimental	Medium
	B5 -- Construct Curb Extensions	Moderate	Tried	Medium to Long

TABLE 3-7
Infrastructure Strategies Addressing Bicycle Crashes on Urban Roadways Considered at Safety Workshops

Objectives	Strategies	Relative Cost to Implement and Operate	Effectiveness	Typical Timeframe for Implementation
A Reduce bicycle crashes at intersections	A1 -- Improve visibility at intersections	Moderate / High	Tried	Long
	A2 -- Improve signal timing and detection	Low / Moderate	Tried	Short
	A3 -- Improve signing	Low	Tried	Short
	A4 -- Improve pavement markings at intersections	Low	Tried	Short
	A5 -- Improve intersections geometry	High	Tried	Long
	A6 -- Restrict right turn on red (RTOR) movements	Low	Experimental	Short
	A7 -- Provide an overpass or underpass	High	Tried	Long
	A8 -- Addition of Bike Boxes	Low	Tried	Short
B Reduce bicycle crashes along roadways	B1 -- Provide safe bicycle facilities for parallel travel -- On/Off Road Facilities, Shoulders, Dedicated	Low to High	Tried	Long
C Reduce motor vehicle speeds	C1 -- Implement traffic calming techniques	Moderate to High	Proven	Long

TABLE 3-8
Behavior-based Safety Strategies Addressing Impaired Crashes Considered at Safety Workshops

Objectives	Strategies	Programs & Tactics	Effectiveness	Impact
A Eliminate Drinking and Driving	A1 -- Require responsible beverage service policies for alcohol servers and retailers	Advocate for server training and strong management support	Proven	Medium
	A2 -- Employ screening and brief interventions	These do not need to be in health care settings. A screening and brief intervention could be very effective after a DWI arrest (traumatic event)	Tried	Medium
	A3 -- Support community programs for alternative transportation*	Safe Cab is a partnership between beer distributors, bar owners and community program in Isanti County.	Tried	Medium
B Enforce DWI Laws	B1 -- Conduct Regular Well-Publicized DWI Saturations*	A saturation is a multi-agency, multi-squad car enforcement effort. These agencies and cars enforce the same community or roadway with the number of squad cars proportionate to the community size.	Proven	High
	B2 -- Conduct education and awareness campaign of the targeted enforcement of Zero Tolerance Laws for Drivers Under Age 21*	<u>Publicizing</u> is best done through community events for the local media and a public education campaign in the community about the enforcement. <u>High visibility enforcement</u> is when multiple jurisdictions and/or multiple squads are out at the same time patrolling in brightly colored vests and signage about the enforcement.	Proven	Low
C Control High-BAC and Repeat Offenders	C1 -- Monitor convicted DWI offenders closely	DWI courts or intensive supervision programs	Proven	Low

TABLE 3-9
Behavior-based Safety Strategies Addressing Unbelted Vehicle Occupant Crashes Considered at Safety Workshops

Objectives	Strategies	Programs & Tactics*	Effectiveness	Impact
A Maximize use of occupant restraints by all vehicle occupants	A1 -- Conduct highly publicized enforcement campaigns to maximize restraint use. Specifically, night time belt enforcement saturation.	Publicizing is best done through community events for the local media and a public education campaign in the community about the enforcement. High visibility enforcement is when multiple jurisdictions and/or multiple squads are out at the same time patrolling in brightly colored vests and signage about the enforcement. Methods for night time enforcement include having multi-agency and multiple squad cars in well lit areas where slow moving vehicles are passing and conducting for a limited time slot.	Proven	High
B Ensure that restraints, especially child and infant restraints, are properly used	B1 -- Conduct high-profile "child restraint inspection" events at multiple community locations.	N/A	Proven	Low
	B2 -- Train advocates to check for proper child restraint use.	N/A	Tried	Low
	C1 -- Encourage employers to 1) offer education programs to employees and to 2) enact traffic safety policies with clear consequences for failure to comply.	Utilize materials and policy statements designed for employers by Network of Employers for Traffic Safety	Proven	

The final short list of high-priority infrastructure related safety strategies that came through the screening process and is documented in every County's Safety Plan (Table 3-10) addresses the target kinds of crashes that are over represented in both rural and urban areas. The list of strategies is consistent with the acknowledged desire of the safety program managers and includes mostly, but not exclusively, proven effective and low-cost strategies such as the following:

TABLE 3-10
Proposed Strategies Effectiveness and Crash Reduction Factors

Strategy	Crash Reduction Factor[a]
Urban	
Conversions (3-lane/5-lane)	30% to 50%
Access Management	5% to 31%
Signal - Confirmation Lights	25% to 84% reduction in violations
Pedestrian/Bike - Advanced Walk	Up to 60% ped/vehicle crashes
Pedestrian/Bike - Countdown Timers	25% ped/vehicle crashes
Pedestrian/Bike - Curb Extensions	Increase in vehicles yielding to pedestrians
Pedestrian/Bike - Median Refuge Island	46% in vehicle/pedestrian crashes
Rural Segments	
6-inch Latex Edge Line	10% to 45% all rural serious crashes
Rumble Strip/stripE	20% run off road crashes
2-ft Paved Shoulder + Rumble Strip	20% to 30% run off road crashes
Centerline Rumble Strip	40% head on/sideswipe crashes
4-ft Buffer	Under Evaluation[b]
12-ft Buffer with Left Turn Lanes	50% all crashes / 100% head-on crashes[c]
Rural Curves	
Chevrons	20% to 30%
Edgeline Rumble Strip	20% run off road crashes
2-ft Paved Shoulder + Rumble Strip	20% to 30% run off road crashes
Rural Intersections	
Roundabout	20% - 50% All Crashes / 60% - 90% right angle
RCI, or J-Turn	17% all crashes / 100% angle crashes
Mainline Dynamic Warning Sign	50% all crashes / 75% severe right angle crashes
Intersection Lighting	25% to 40% nighttime crashes
Upgrade Signs and Markings	40% upgrade of all signs and marking / 15% for STOP AHEAD marking
Clear Sight Triangle	37% serious injury crashes[d]

[a] Crash reduction factors based on review of CMF Clearinghouse and other published research
[b] MnDOT experience on TH 12 in Long Lake
[c] MnDOT experience on TH 5 in Lake Elmo
[d] Reduction based on increasing sight distance triangle

- Edge rumbles and curve delineation for rural segments
- Street lighting at rural intersections
- Countdown timers, curb extensions, and medians for pedestrians at urban intersections
- Road diets for urban segments

The final list also includes a number of experimental and higher-cost safety strategies, such as reduced conflict intersections, dynamic warning signs, and roundabouts. This final list of strategies contained one additional enhancement – a crash reduction factor (CRF) was provided for each safety strategy, along with a source to lend factual support for the effectiveness of each of the strategies to actually reduce particular crash types. These high-priority strategies then became the basis for the development of safety projects in a subsequent step.

System-Wide Risk Assessment

The most unique and innovative component of the analytical process that supported the development of the County Roadway Safety Plans was conducting risk assessments along road segments and horizontal curves and at intersections. Risk factors were used to identify candidate locations for safety investment due to the poor outcomes associated with previous attempts to develop safety projects on rural road systems using the site analysis approach (which had been used successfully to identify high crash locations for many years). The challenge was that there were very few locations along rural, local road systems in Minnesota that met the adopted thresholds to qualify as black spots. In addition, it was expected that the analysis of the county roadway system would confirm two key points:

1. Severe crashes would not be either randomly or uniformly distributed along county roadways
2. Certain identifiable roadway and traffic characteristics would likely be associated with the locations that have higher-than-average densities of severe crashes

An example of the second point is the relationship between horizontal curves and an increased probability of road departure crashes along rural roadways. For years, the literature had suggested that there was a relationship, but no additional insight was provided about whether this relationship applied to all curves or only some, or if the frequency of curves (the number of curves per mile) played any role.

Because of concerns about applying the traditional site analysis approach to rural county roadways, it was decided that the analytical process used in the County Roadway Safety Plans would look for locations with multiple severe crashes but would primarily use an accumulation of risk factors to identify candidate locations for safety investment. The notion of using risk factors in addition to crash history to conduct a system wide safety screening had not been the subject of rigorous, prior research and as a result, there was very little in the way of guidance related to either the identification/selection of risk factors or their application. Therefore, the entire process had to be developed and refined as part of the County Roadway Safety Plan project.

The initial identification of risk factors – basically roadway and traffic characteristics that could be identified by using photo inventories, aerial photography, geographic information system (GIS), and various electronic data bases – was based on a review of published safety research, including:

- NCHRP Report 500 Series, *Guidance for Implementation of the AASHTO Strategic Highway Safety Plan Transportation Research*
- NCHRP Report 650, *Median Intersection Design for Rural High-Speed Divided Highways*
- Texas Transportation Institute (TTI) – Rural, Horizontal Curves
- Center for Transportation Research and Education (CTRE), *Rural Expressway Intersection Synthesis of Practice and Crash Analysis*
- ASSHTO *Highway Safety Manual*
- MnDOT – Rural Through/STOP Intersections and Rural Segments Curves

The risk factors selected for the system wide safety assessment were chosen based on the evidence in the literature and, in some cases, with support from a crash analysis of a small sample of Minnesota's rural roadways that these roadway and traffic characteristics appeared to be overrepresented at locations where severe crashes occurred. The risk factors selected and the range of values used to identify the at-risk locations are provided in the following bullets.

Rural Segments

- Density of road-departure crashes – The density of annual road departure crashes per mile was computed for each roadway segment within a county. Any segment above the county's average was identified as at-risk. In Greater Minnesota, the average road departure crash density ranged from 0.01 to 0.26 road departure crash per mile, and in the Metropolitan Area, the density ranged from 0.13 to 0.55 crash per mile. [Note: The last phase actually used lane departure crash density rather than road departure crash density.]
- Range of average daily traffic (ADT) volume – Set an at-risk range for each ATP, the low end of the range varied from 250 to 1,500 vehicles per day and the high end varied from 500 vehicles per day to unlimited. [Note: The first phase set at-risk ADT ranges for each county while the remaining phases used at-risk ADT ranges for each ATP.]
- Curve density (with radii in the critical range) – Computed on a county by county basis, any segment above the county's average was identified as at-risk. The average curve density ranged from 0.06 to 1.8 critical radius curves per mile.
- Access density – Computed on a county-by-county basis (Phases II through IV only), any segment above the county's average was identified as at-risk. The average access density range from 3.2 to 15.3 access points per mile in the Greater Minnesota counties and from 11.4 to 20.1 access points per mile in the Metropolitan Area counties.
- Edge risk assessment – Assigned by analysts to each segment on a county-by-county basis, a value of 1 indicates a good road edge with usable shoulder, shoulder slope, and ditch and a value of 3 indicates a poor road edge with no usable shoulder, steep shoulder slopes, and obstacles in the ditch. Road segments with edge ratings of 2 and 3 were considered at risk (Figure 4-1).

Rural Paved Horizontal Curves

- Occurrence of a severe crash
- Range of curve radii – Curves radius between 500 and 1,200 feet was typically used to identify at-risk locations.
- Range of average daily traffic (ADT) volume – Set an at-risk range for each ATP, the low end of the range varied from 200 to 1,500 vehicles per day and the high end varied from 500 vehicles per day to unlimited. [Note: The first phase set at-risk curve ADT ranges for each county while the remaining phases used at-risk curve ADT ranges for each ATP.]
- Presence of an intersection
- Presence of a visual trap

Rural Intersections

- Occurrence of an intersection-related crash
- Skewed minor approaches (at least 15 degrees of skew)
- In/near a curve
- Average daily traffic (ADT) volume – The ratio of minor road daily traffic to major road daily traffic was computed for every intersection on a county-by-county basis. The low end of the range varied

from 0.0 to 0.6 ratio of minor ADT to major ADT and the high end of the range varied from 0.2 to 1.0 ratio. [Note: The first phase set at-risk ADT ratio range for each county while the remaining phases used at-risk ADT ratio ranges for each ATP.]

- Proximity to a railroad crossing
- Distance to the previous STOP sign – A distance of greater than 5 miles from the previous STOP sign along the approach to the next STOP sign was consider to be a risk (Figure 4-2).
- Presence of commercial development

1 – Usable Shoulder, Reasonable Clear Zone

2 – No Usable Shoulder, Reasonable Clear Zone

2 – Usable Shoulder, Roadside with Fixed Obstacles

3 – No Usable Shoulder, Roadside with Fixed Obstacles

FIGURE 4-1
Sample Edge Risk Assessment Photos

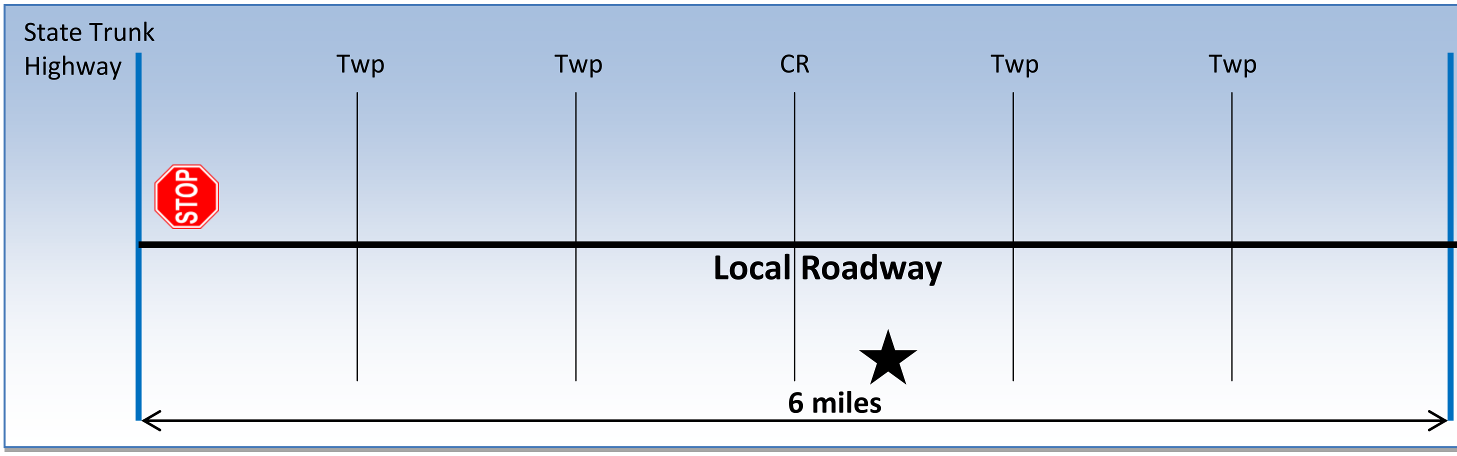


FIGURE 4-2
Illustration of Rural Intersection Risk Factor of Greater than 5 Miles to Previous STOP Sign

Urban Segments

- Occurrence of a severe rear-end/sideswipe-opposing/head-on crash
- Average daily traffic (ADT) volume – Volumes greater than 10,000 vehicles per day was considered at-risk.
- Number of lanes (major approaches) – Roadways with four or more lanes were considered at-risk.
- Access density – Densities between 15 and 60 access points per mile were considered at-risk.
- Speed limit – Speed limits of 40 miles per hour (mph) or less was considered at-risk.

Urban Intersections – Angle Crashes

- Occurrence of a severe right-angle crash
- Speed limit (major road) – Speed limits of 45 to 55 mph was considered at-risk in Carver, Dakota, Scott, and Washington counties. Speed limits of 40 mph or less was considered at-risk in Anoka and Ramsey counties.
- Average daily traffic (ADT) volume (major road) – Volumes greater than or equal to 17,500 vehicles per day was considered at-risk.
- Roadway cross section – Divided roads were considered at-risk in Carver, Dakota, Scott, and Washington counties.

Urban Intersections – Pedestrian/Bicycle Crashes

- Occurrence of a severe pedestrian/bicycle crash
- Average daily traffic (ADT) volume (major road) – Volumes greater than or equal to 17,500 vehicles per day were considered at-risk.
- Number of lanes (major approaches) – Four or more total approach lanes on the major approaches was considered at-risk in Anoka and Ramsey counties.
- Speed limit (major approaches) – Speed limits less than or equal to 40 mph were considered at-risk.

- Roadway Cross Section – Undivided roads were considered at-risk in Carver, Dakota, Scott, and Washington counties.
- Presence of a bus stop
- Presence of a pedestrian generator (commercial or retail land use at/near the intersection, for example, restaurants and coffee shops)
- Presence of on-street parking was considered at-risk in Anoka and Ramsey counties.

As the County Roadway Safety Plan project progressed from phase to phase, one of the closeout tasks prior to initiating the analysis of the next phase consisted of looking back and determining if the various factors were actually associated with higher densities of crashes (greater risk). In almost all cases the answer was yes, the factors were associated with greater risk. As a result, there was a very high level of consistency in the factors in each phase of the County Roadway Safety Plan project. One factor was dropped because of this look-back evaluation (the use of the percentage of No Passing Zone in rural segments could not be correlated with a higher density of road departure crashes) and one factor was added (access density because there was a correlation with a higher frequency of severe crashes). At the end of the project, one final look back at the risk factors was conducted using data from all four phases. The results of this effort revealed the following ability to identify locations with higher densities of crashes using the risk factors.

Rural Roadway Segments

- 26,600 miles of paved county roadways were evaluated.
- 963 severe road departure crashes occurred on these roads over a 5-year period.
- Average crash density = 0.01 severe road departure crashes/mile/year.
- Risk factors identified roadway segments with higher densities of severe road departure crashes; the crash density increased with each additional risk factor.
- The data supports the use of access density, curve density, ADT, and edge risk assessment as risk factors. The density of severe crashes was consistently higher in segments with each factor present compared to the segments without the factor (Figure 4-3).
- Research suggests a relationship between ADT and crashes on rural road segments – as ADT increases, the risk for a crash also increases. However, the data on Minnesota’s county roadways suggests a different relationship. The most severe crashes on Minnesota’s county system involve a single vehicle running off the road – 65 percent of these crashes occur on roads with less than 1,000 vehicles per day and the fraction of these severe crashes decreases as volumes increase (Figure 4-4).
- Roadway segments considered a high priority (those segments with three or more risk factors present) had crash densities above the statewide average. Roadway segments with fewer than three risk factors had crash densities below the statewide average (Figure 4-5).

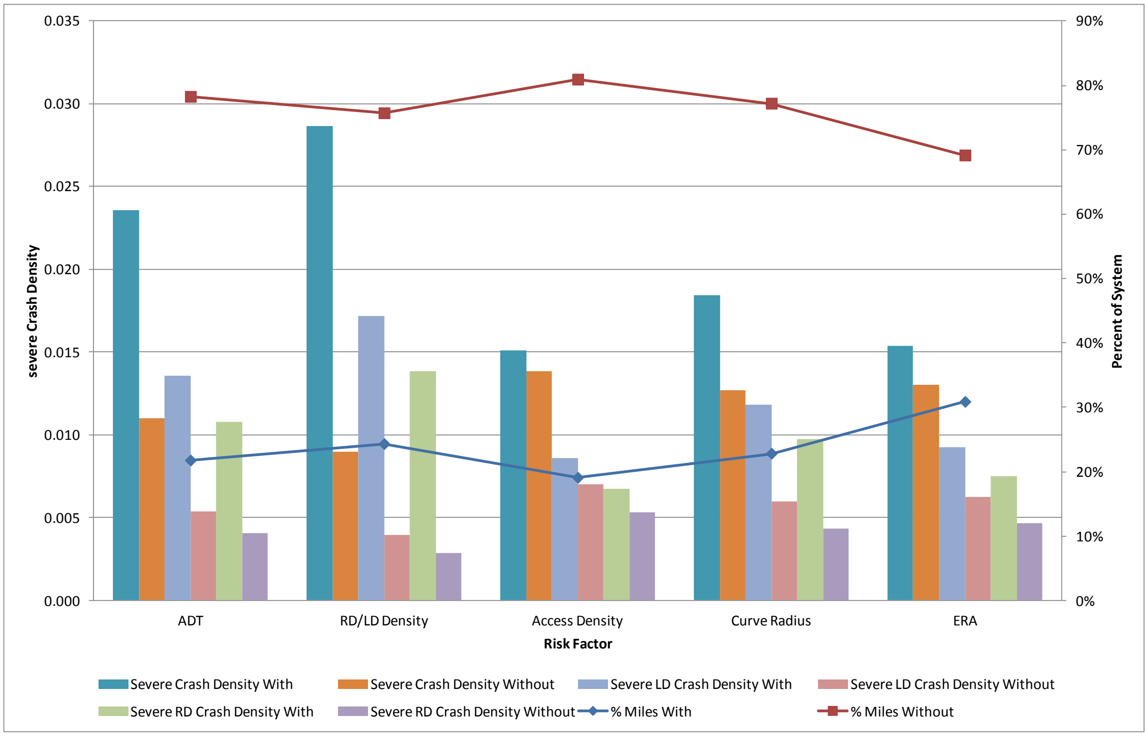


FIGURE 4-3
Severe Crash Densities for Rural Segment Risk Factors

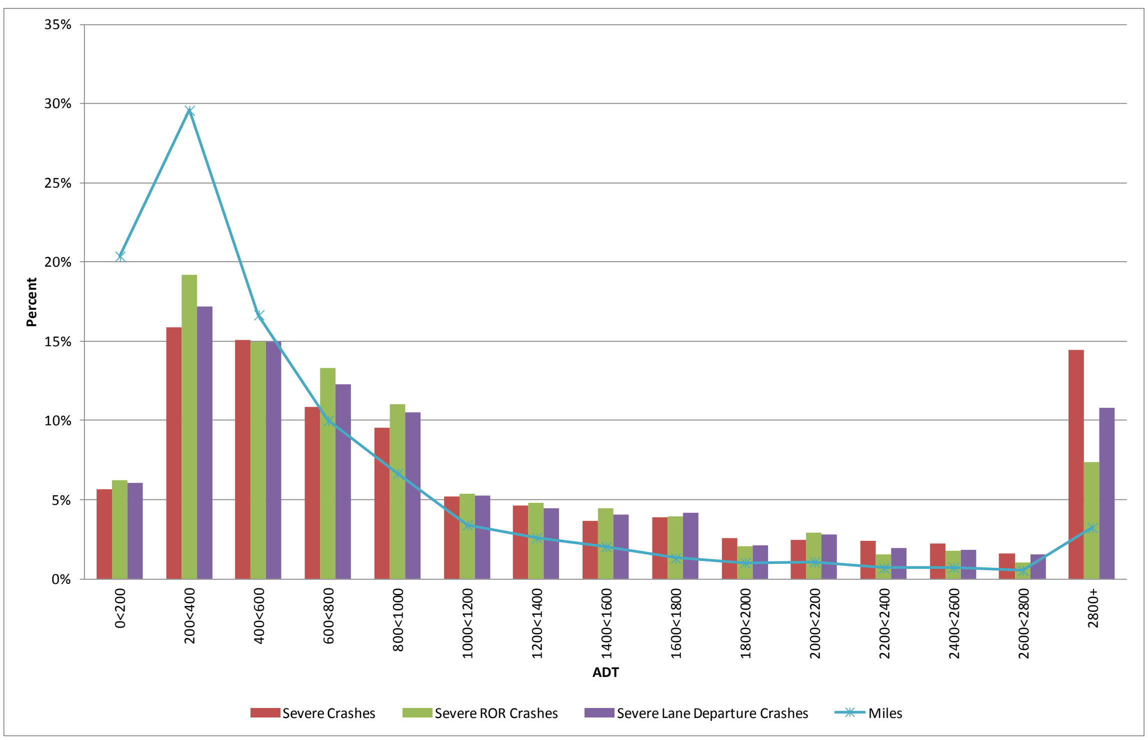


FIGURE 4-4
Severe Segment Crashes by ADT

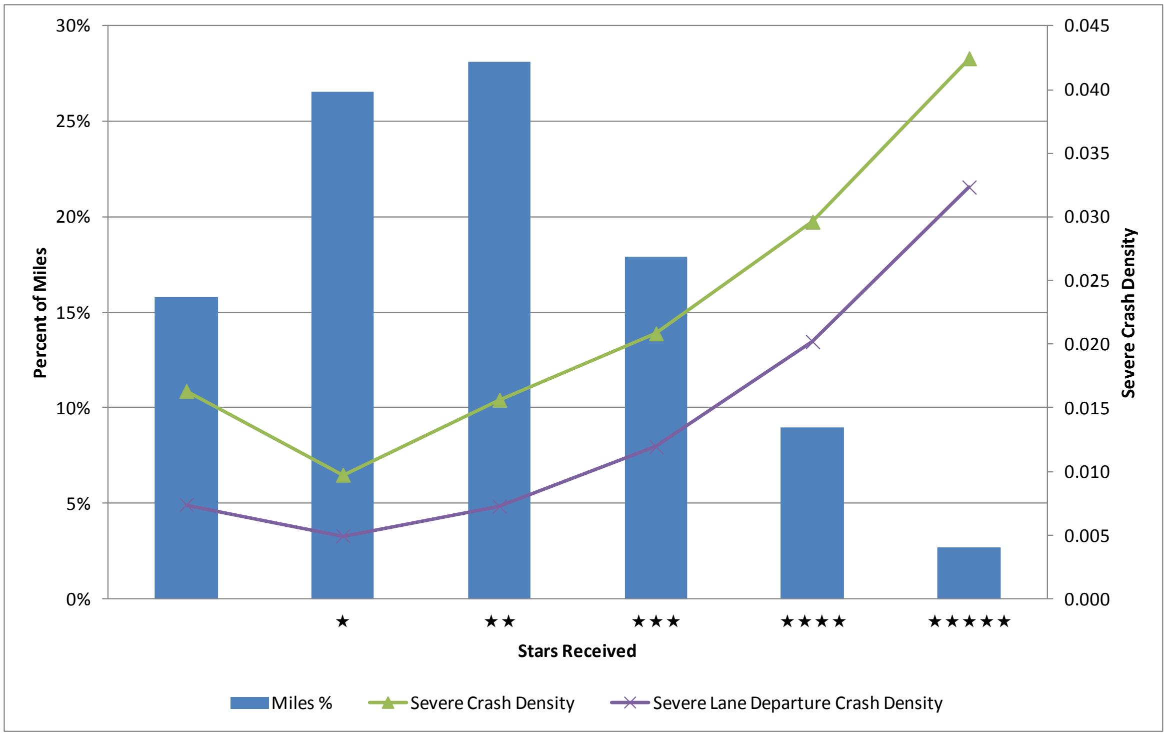


FIGURE 4-5
Miles Distribution and Severe Crash Densities for Rural Segments by Risk Ratings

Rural Paved Horizontal Curves

- 18,959 horizontal curves were evaluated.
- 480 severe crashes occurred in these curves over a 5-year period.
- 97.6 percent of these curves had no severe crashes and 2.3 percent had only one severe crash.
- No curve on the county roadway system averaged one severe crash per year.
- The average crash density = 0.005 severe crashes/curve/year.
- The data supports using curve radii (between 500 and 1,200 feet) as a risk factor. This range of curve radii accounted for approximately 50 percent of the curves along county roadways and 63 percent of severe crashes (Figure 4-6).
- The data supports the use of ADT and the presence of an intersection/visual trap as risk factors – the density of severe crashes was consistently higher in curves with an intersection or visual trap present (Figure 4-7).
- The *Minnesota Manual on Uniform Traffic Control Devices* requires the use of certain curve warning signs, but only on roadways with more than 1,000 vehicles per day. On Minnesota's county roadways, 80 percent of the horizontal curves and 63 percent of the severe curve-related crashes occurred on roadways with volumes less than 1,000 vehicles per day (Figure 4-8).
- Curves considered a high priority (those curves with three or more risk factors present) had crash densities above the statewide average [0.005 severe crashes per curve per year or 0.003 severe road departure crashes per curve per year] (Figure 4-9).

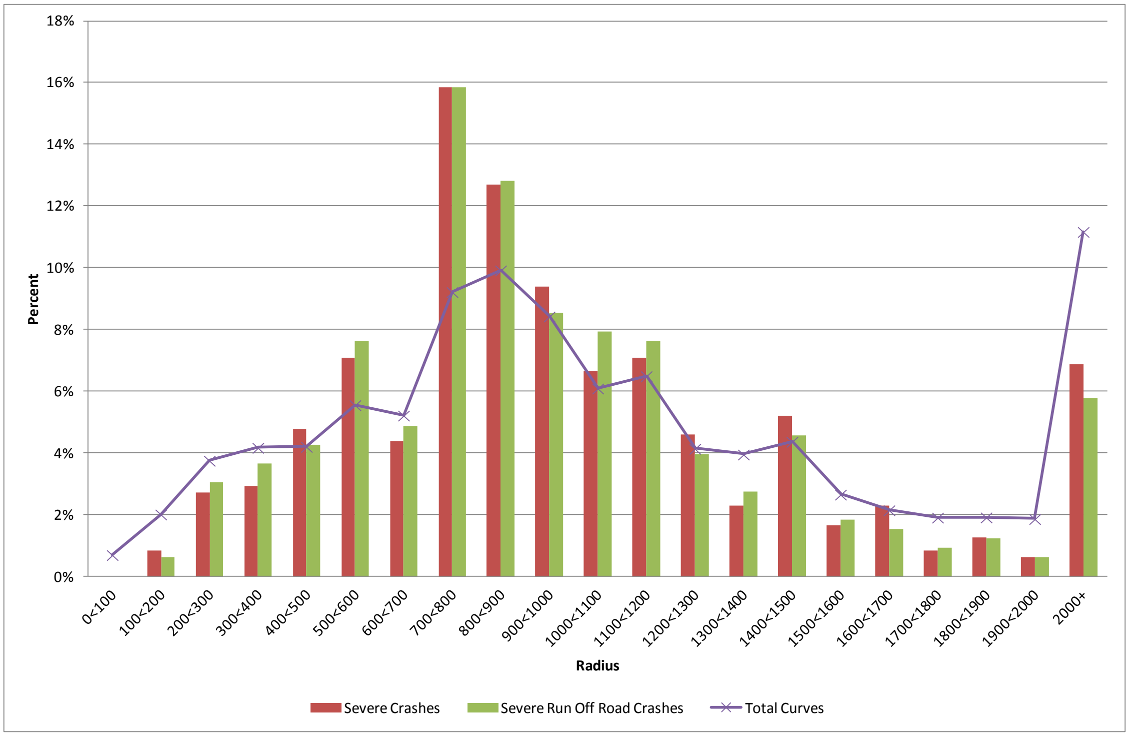


FIGURE 4-6
Severe Crashes by Radius for Rural Paved Curves

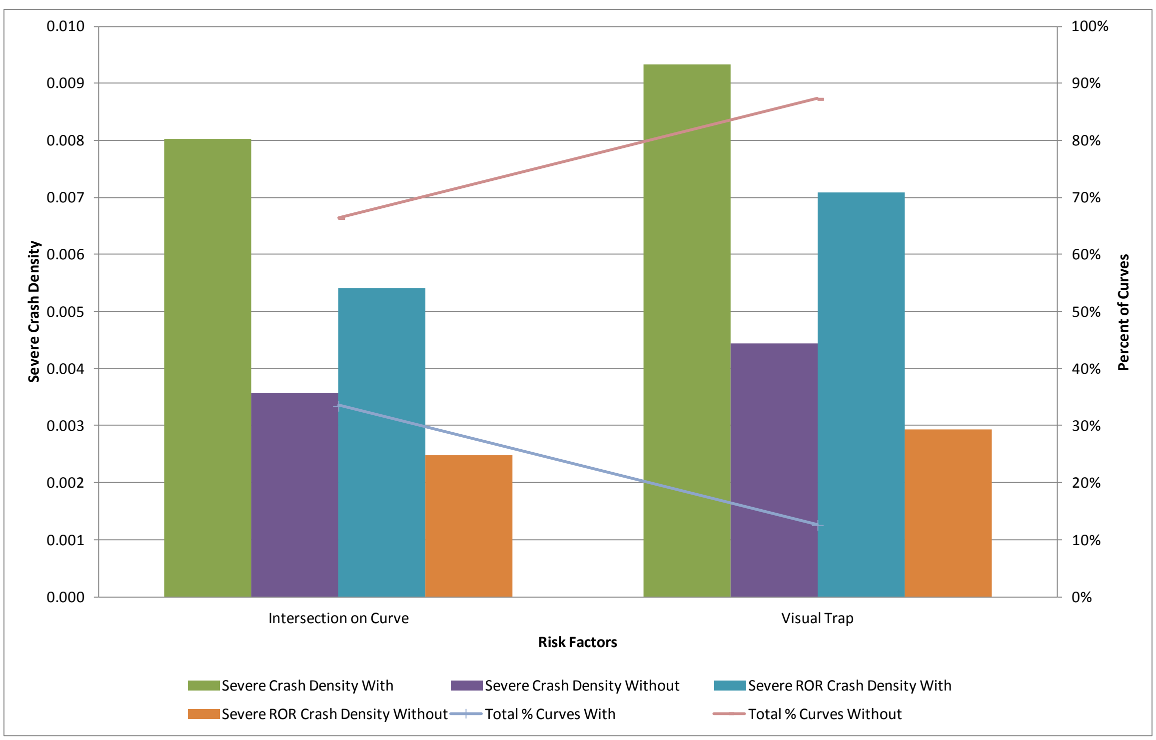


FIGURE 4-7
Severe Crash Densities for Rural Segment Risk Factors

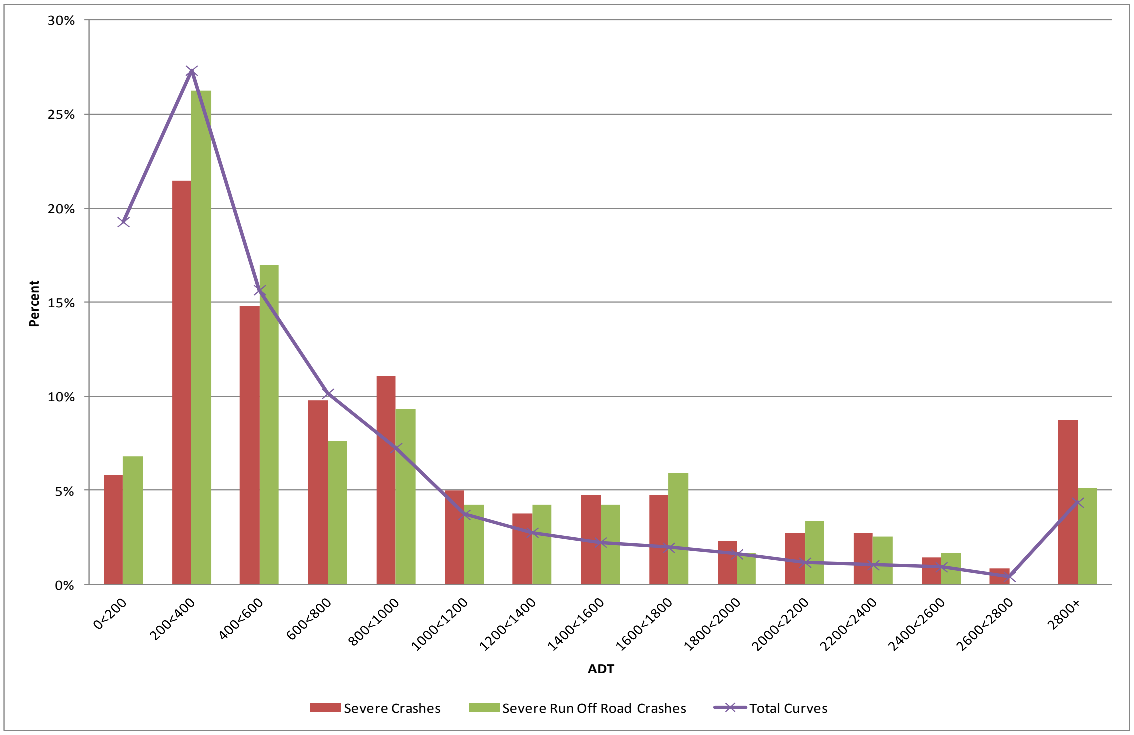


FIGURE 4-8
Severe Crashes by ADT for Rural Paved Curves

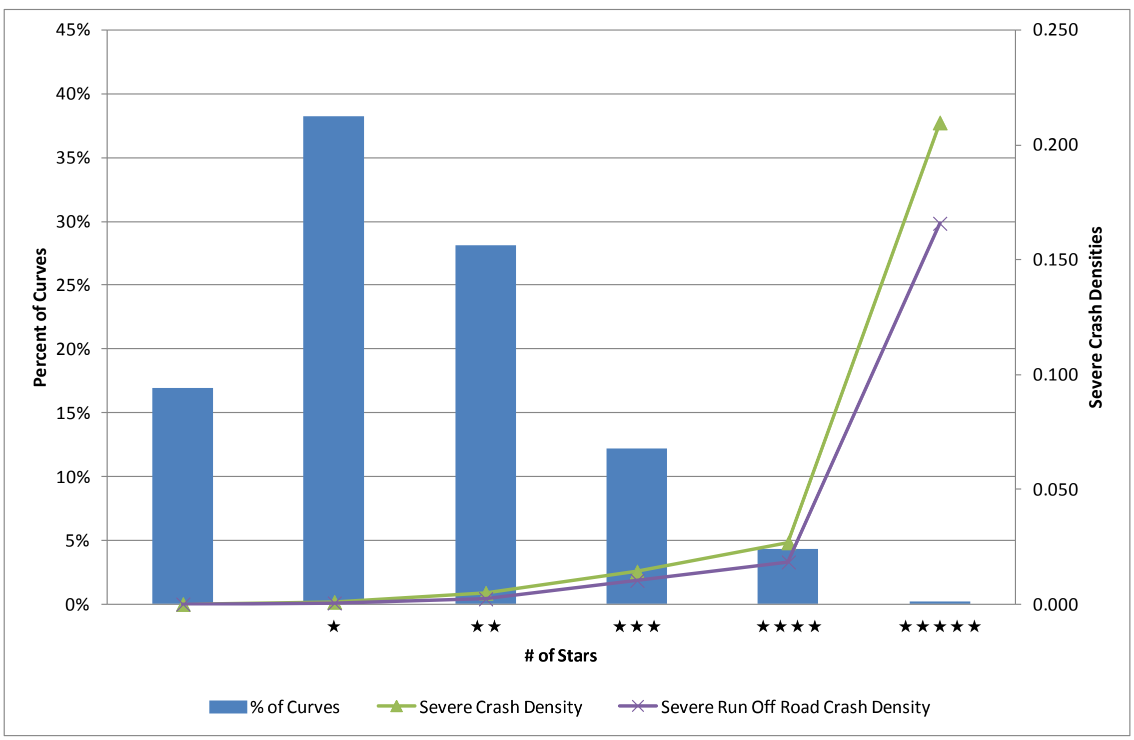


FIGURE 4-9
Curve Distribution and Severe Crash Densities for Rural Paved Curves by Risk Ratings

Rural Intersections

- 12,684 intersections were evaluated.
- 810 severe crashes and 369 severe right-angle crashes occurred at these intersections over a 5-year period.
- The average crash density = 0.013 severe crash/intersection/year.
- At rural thru-stop intersections, 89 percent of these intersections had no severe right-angle crash and 2 percent had one severe right-angle crash.
- Only one rural thru-stop intersection averaged more than one severe right-angle crash per year.
- The data supports the use of proximity to a railroad, skew angle, in/near a curve, commercial development, distance to the last STOP sign, and ADT ratio as risk factors at rural thru-stop intersections. The density of severe and severe right-angle crashes was consistently higher in all cases where the factor was present (Figure 4-10).
- Intersections considered a priority (those intersections with three or more risk factors present) had a crash density above the statewide average (Figure 4-11).

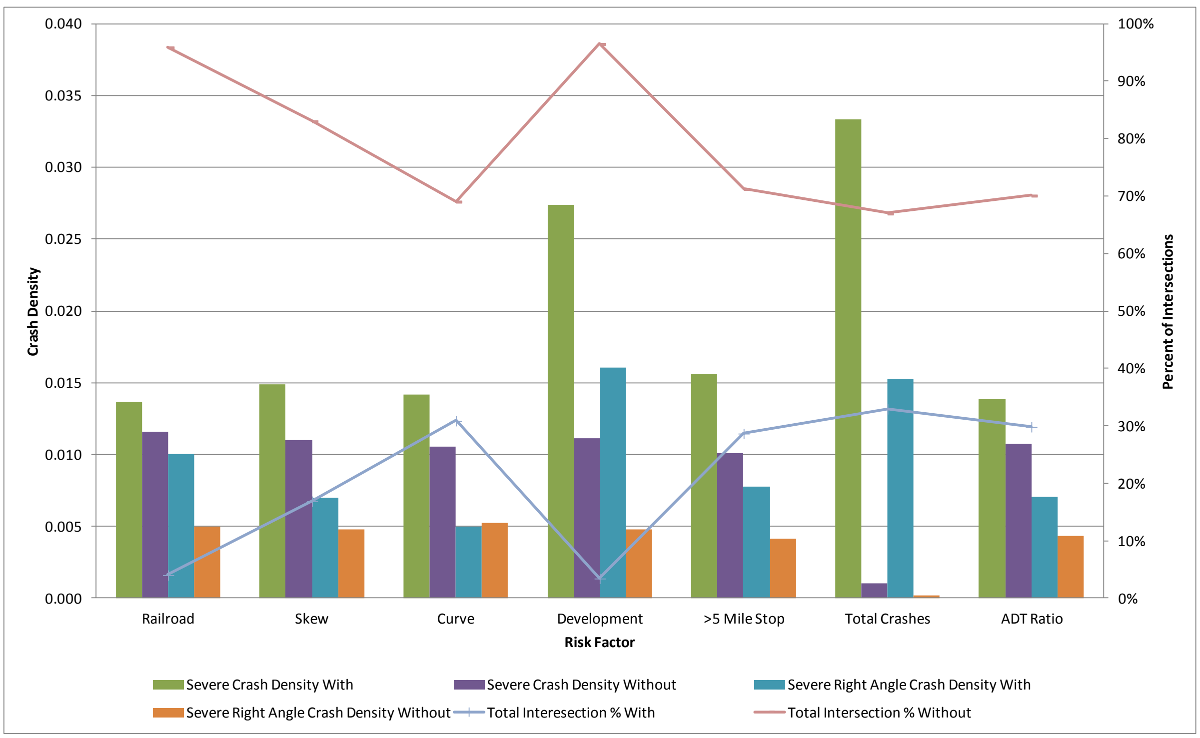


FIGURE 4-10
Severe Crash Densities for Rural Intersection Risk Factors

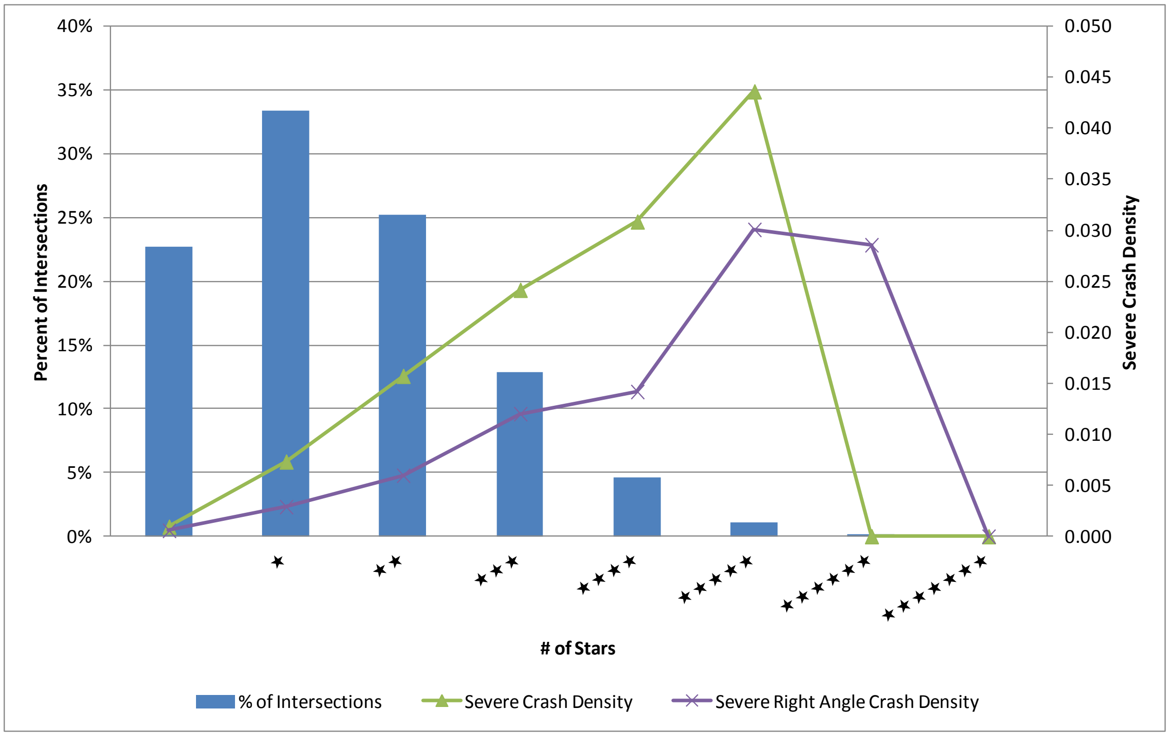


FIGURE 4-11
Intersection Distribution and Severe Crash Densities for Rural Intersections by Risk Ratings

Metro Area Urban Segments

- 1,595 miles of urban county roadways were evaluated.
- 431 severe rear-end/sideswipe-opposing/head-on crashes occurred over a 5-year period.
- The data supports the use of volume, speed, access density, and roadway cross-section as risk factors.

Metro Area Urban Intersections

- 2,856 urban intersections were evaluated.
- 253 severe right-angle crashes and 164 severe pedestrian/bicycle involved crashes occurred over a five year period.
- Approximately 80% of these intersections had no severe crashes and 14% had one severe crash.
- No intersection averaged one severe right angle or severe pedestrian/bicycle crash per year.
- The average crash density = 0.02 severe right angle crashes/intersection/year and 0.01 severe pedestrian-bicycle crashes/intersection/year.
- For severe right angle crashes at signalized intersections, the data support the use of the following risk factors:
  - Intersection control (81% of severe right angle crashes at signalized intersections)
  - ADT (41% of severe right angle crashes at entering ADT >17,500 vehicles per day)
  - Speed (59% of severe right angle crashes at speeds of 40 miles per hour or less)

  - Roadway cross-section (50% of severe right angle crashes were on divided roadways in Carver, Dakota, Scott and Washington counties).

- For severe pedestrian/bicycle crashes at intersections, the data supports the use of the following risk factors:
  - Intersection control (87 percent of severe pedestrian/bicycle crashes at signalized intersections)
  - Speed (70 percent of severe pedestrian/bicycle crashes at speeds at or below 40 mph)
  - Roadway cross-section (46 percent of severe pedestrian/bicycle crashes on undivided roadways)
  - Presence of a bus stop (69 percent of severe pedestrian/bicycle crashes)
  - Presence of a pedestrian generator (63 percent of pedestrian/bicycle crashes)
- Further support for the use of the urban intersection risk factors relates to the fact that roadway corridors that contain multiple high-priority intersections for right-angle and pedestrian/bicycle crashes have densities of those kinds of crashes that are four to six times higher than the average for all Metropolitan Area urban county roadways.

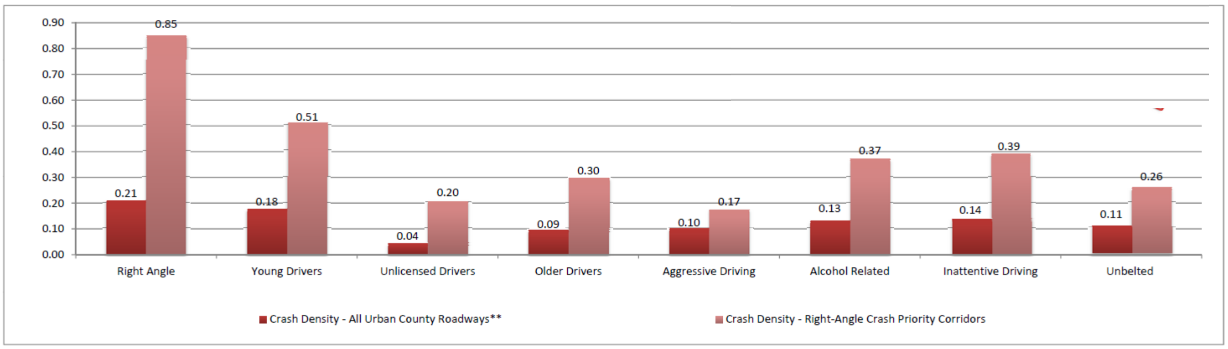
The application of the risk factors was part of the system-wide evaluation that was conducted by analysts in each of Minnesota's 87 counties and focused on roadway segments, horizontal curves, and intersections. In Greater Minnesota, the assessment was conducted on all paved rural roads (where more than 80 percent of severe crashes occur), with a focus on roadway segments, horizontal curves, and intersections. In the Metropolitan Area, the assessment included the paved rural roads (except in Hennepin and Ramsey counties where there are too few rural roads and, hence, very few severe crashes) plus all of the urban segments with a focus on both segments and intersections. The risk assessments were conducted using photo inventories, aerial photography, and various electronic databases, including crash records (MnCMAT), traffic volumes, sign inventories, and speed limits. The results of the risk assessments were tabulated and recorded on spreadsheets and provided to each county for review and concurrence. The final, edited versions of the spreadsheets were included as part of each county's Safety Plan. The result of the system-wide risk assessment was a ranking of roadway segments, curves, and intersections based on the number of risk factors present for each.

The primary objective for applying the risk factors as part of a system-wide safety assessment was to identify the fraction of each county's road system – roadway segments, curves, and intersections – that were at the greatest risk for severe crashes. The process initially assumed and then proved that the locations with an accumulation of risk factors represented the highest-priority candidates for safety investment – the greater the numbers of risk factors present at any location, the greater the risk for a severe crash. Safety projects were then developed for this subset of priority locations that were determined to be eligible for HSIP funding. The safety projects could then be implemented proactively by the counties to prevent the most severe types of crashes occurring along their road systems.

One final point about the application of risk factors should be noted. Using risk factors to identify locations for safety investment was limited to infrastructure improvements. However, as part of the effort to look back at the data from all phases of the County Roadway Safety Plan project, the possibility of a relationship between the risk factors and driver-behavior crashes was investigated. Specifically, the data for urban roadway segments in the Metropolitan Area counties was reviewed and densities of driver-behavioral crashes was computed for all urban county roadways and then compared to the densities in the corridors considered high priority for right-angle and pedestrian/bicycle crashes. The results (Figure 4-12) suggest that the corridors identified as a high priority for right-angle and pedestrian/bicycle crashes also have noticeably higher densities of crashes involving young drivers, inattentive driving, alcohol impairment, and older drivers. This indicates the possibility of using a similar risk assessment approach to help direct law enforcement resources to specific corridors where their efforts could result in large decreases in severe crashes.

		Young Drivers		Unlicensed Drivers		Older Drivers		Aggressive Driving		Alcohol Related		Inattentive Driving		Unbelted	
Stars	Miles	Crashes	*Density*	Crashes	*Density*	Crashes	*Density*	Crashes	*Density*	Crashes	*Density*	Crashes	*Density*	Crashes	*Density*
All Metro Urban CR/CSAHs**	**1,035**	**182**	***0.18***	**42**	***0.04***	**97**	***0.09***	**102**	***0.10***	**134**	***0.13***	**140**	***0.14***	**111**	***0.11***
Priority Corridors	**98**	**50**	***0.51***	**20**	***0.20***	**29**	***0.30***	**17**	***0.17***	**36**	***0.37***	**38**	***0.39***	**25**	***0.26***

		Right Angle		Signalized		Unsignalized		Pedestrian Crashes		Bicycle Crashes		Motorcycles		Heavy Vehicle	
Stars	Miles	Crashes	*Density*	Crashes	*Density*	Crashes	*Density*	Crashes	*Density*	Crashes	*Density*	Crashes	*Density*	Crashes	*Density*
All Metro Urban CR/CSAHs**	**1,035**	**216**	***0.21***	**176**	***0.17***	**169**	***0.16***	**67**	***0.06***	**51**	***0.05***	**132**	***0.13***	**49**	***0.05***
Priority Corridors	**98**	**83**	***0.85***	**99**	***1.01***	**39**	***0.40***	**36**	***0.37***	**19**	***0.19***	**30**	***0.31***	**11**	***0.11***



**Anoka, Carver, Dakota, Ramsey, Scott and Washington Counties

FIGURE 4-12
Behavior Crashes in Priority Right Angle Crash Corridors in the Metro Area

Project Development

The basic objective of the effort to provide every county in Minnesota with their own County Roadway Safety Plan was to help the county highway departments proactively implement safety projects along at-risk locations, thereby reducing specific types of crashes.

The effort to describe safety projects included a focus on consistency among the counties - a high level of importance was placed on developing similar projects for locations with similar characteristics across the entire county roadway system. In order to help achieve this high level of consistency (final project descriptions were occasionally adjusted to reflect the individual preferences of the various county engineers), project development decision trees were prepared for use by all of the analysts. The decision trees for rural segments and rural intersections began with identifying roadway and traffic features (that is, paved versus gravel road surface, lane width, traffic volume) and depending on the exact features present at specific locations pointed the analysts towards a specific safety improvement strategy that had been determined to be suitable for a specific combination of characteristics.

The approach to safety project development implicit in the rural segment decision tree (Figure 5-1) focused on providing an enhanced road edge and includes:

- All identified high priority rural segments would receive a project, but low volume segments (that is, low exposure) would receive lower cost improvements (generally enhanced pavement markings) than higher volume (that is, greater exposure) segments (generally some type of edge rumble).
- Edge rumbles were not suggest for segments that were identified as “Noise Sensitive” (usually high densities of residential development) because of the high level of complaints that resulted in some early rumble projects having to be paved over. As a result an embedded wet-reflective marking was suggested.
- For all of the remaining higher volume, not noise sensitive segments, some type of edge rumble was initially suggested. Project included either a shoulder rumble strip where there were paved shoulders, an edge line rumble strip where there were gravel shoulders, and narrow shoulder paving (2 feet) with an edge line rumble strip and a safety edge was suggested in a limited number of locations.

The approach to safety project development implicit in the rural intersection decision tree (Figure 5-2) focused on providing enhanced intersection recognition or a reduction in the number of intersection conflicts and includes:

- All identified high priority rural intersections would receive a project, but low volume intersections would receive less costly improvements (generally upgraded signs and pavement markings), higher volume intersections would receive more costly improvements (street lights) and the highest volume intersections would receive the most costly improvements (dynamic warning signs or possibly directional medians at intersections with multi-lane divided state highways).

The approach to safety project development for rural horizontal curves was simpler; the same project was suggested for all identified high priority curves – enhanced delineation by adding chevrons (and possibly advance warning signs depending on the speed reduction), upgrade of the road edge by adding a 2-foot paved shoulder (assumes there is a 2 foot paved shoulder in place) with a shoulder rumble strip and a safety edge.

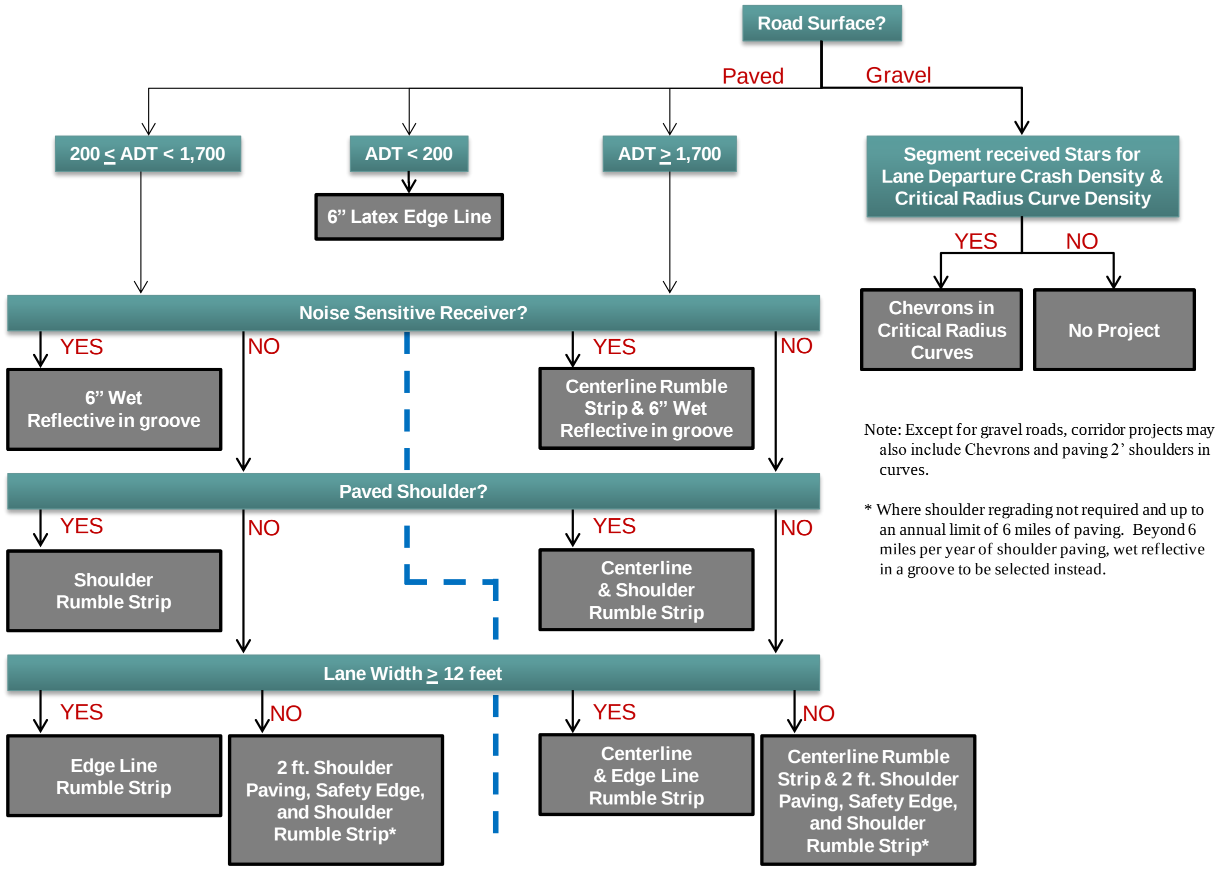


FIGURE 5-1
Rural Segment Project Type Decision Process

The approach to developing safety projects in urban areas was also simpler, primarily because there were a limited number of strategies determined to be both effective and low-cost. Urban segments determined to be at-risk for right-angle crashes at signals, confirmation lights were suggested at signalized locations. Urban segments determined to be at-risk for pedestrian crashes, count-down timers plus the addition of a leading pedestrian interval were suggested at signalized intersections while curb extensions or median pedestrian refuges were considerations for unsignalized intersections. In urban segments determined to be at-risk for rear-end and/or head-on crashes, conversion to three or five lanes was suggested if the conversion could be accomplished without moving the curb line.

The effort of moving from an initial list of projects for each county to a final list was iterative and involved at least one (and sometimes several) discussions with the county engineer. The initial list of projects came directly from the analyst's use of the crash trees and the final list in most cases was customized to reflect individual county engineer's preferences. The last step in the safety project development process involved the preparation of a project sheet for each of the projects included on each county's final list. This project sheet accomplished two key objectives. First, describing in detail the strategy to be deployed, the specific location on the county system where the strategy was to be implemented and the estimated first cost of deployment. Second, the project sheet is the form the counties can use in response to MnDOT's solicitation for the HSIP. The project sheet is organized and includes all of the information required by MnDOT staff to evaluate candidate projects for inclusion in the highway safety improvement program. The response to the development of this project sheet was very positive by both county engineers (the project sheet made it easy to submit a project for HSIP funding – prior to the development of the project sheet, it had been suggested that the effort to generate a funding request on their own had prevented some county engineers for participating in the safety program) and MnDOT staff (the project sheet substantially reduced the time it had previously taken to correct or complete forms that did not include all necessary information about candidate projects). An example of a project sheet for rural and urban projects is illustrated in Figures 5-3.

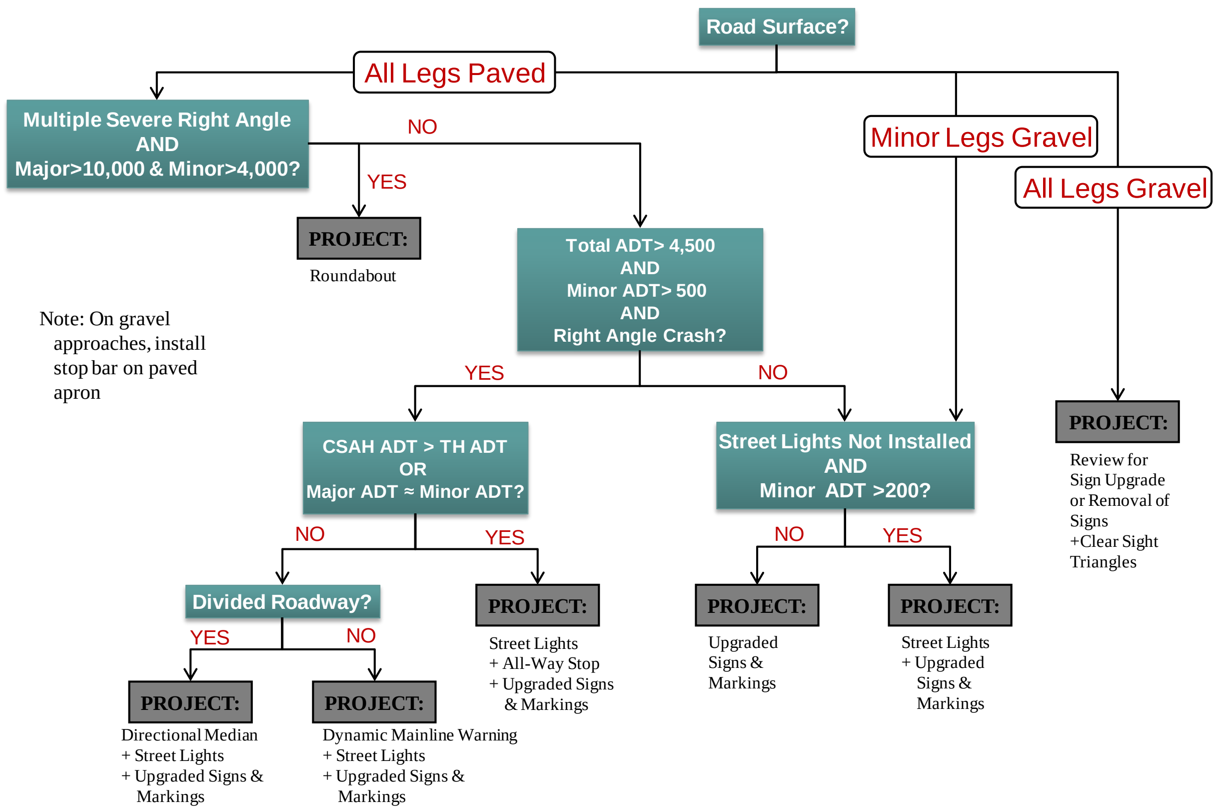


FIGURE 5-2
Rural Intersection Project Type Decision Process

With regard to the amount of projects identified as a result of the County Roadway Safety Plans, the initial objective for the plans was to identify between $2 million and $3 million of low-cost projects for each county. It was acknowledged that this amount would be more than any county could implement in one year and more than what could be funded by HSIP (at current levels) in ten years. However, providing the counties with a (reasonable) backlog of projects was considered very important in order to provide the county engineers flexibility selecting projects for implementation. It additionally recognized that multiple years of projects is desirable because MnDOT does not currently plan to provide the counties with technical assistance to update the project lists. The Safety Plans for the 87 counties identified and described 17,167 projects with an estimated implementation cost of $245.82 million, an average of $2.82 million of projects per county and $14,300 per project. A further breakdown and summary of the suggested safety projects is provided in Table 5-1 and in the following bullet points.

CSAH 33 from CSAH-8 to CSAH-12 Project

Agency: Beltrami County

Roadway Data

Type:	CSAH
Number:	33
	Verbal
Start:	CSAH-8
End:	CSAH-12
City/Rural:	-
County:	Beltrami
ATP:	2
ADT:	1150
Facility Type:	2-Lane
Lane Width:	12
Speed Limit:	
Shoulder Width:	0'
Shoulder Type:	Turf
Length (miles):	5.9
Rumble Installed:	no

Crash Data

2006-2010 MnCMAT Crash Data 5 years

	Total	Road Dept	K+A
Crashes	8	4	1
Density (per mile per year)	0.27	0.14	0.03
Rate (per MVM)	0.65	0.32	0.08

Ranking Criteria

	Value	Critical	Road Departure Risk Ranking
ADT Range	1,150	> 600	★
RD Density	0.17	0.10	★
Access Density	9.7	11.70	
Curve Critical Radius Density	1.19	0.42	★
Edge Risk	3	2 or 3	★
			★★★★

Short List of Strategies Considered

Description	Type	Cost per mi	Mileage	Cost
2' Shoulder Pave+RS+Safety Wedge	Proactive	$40,000	0.0	$0
Rumble Strip	Proactive	$3,000	0.0	$0
Rumble StripE	Proactive	$3,500	5.9	$20,650
6" Edge Lines	Proactive	$650	0.0	$0
Ground In Wet-Reflective Markings	Proactive	$8,500	1.5	$12,538
Center Line Rumble Strip	Proactive	$3,000	0.0	$0
6" Center Line	Proactive	$650	0.0	$0

Notes - The south end of the corridor (~ 1.5 miles) was identified as Noise Sensitive. The project in the noise sensitive area inculdes paved shoulders (for consistency) with embedded wet reflectvie edge lines.

Implementation Cost

Federal Funds	$29,869
Local Match (10% of Total project cost)	$3,319
Total Project Cost	**$33,188**

Page: 5
Segment ID: 33.01
Date: 12/17/2012

FIGURE 5-3
Example Project Form

TABLE 5-1
Summary of Suggested Safety Projects

Project Type	Number of Projects	Estimated Cost (Millions)	Average Cost
Rural Projects			
Rural Segments	2,090	$109.37	$51,300
Rural Curves	10,757	$79.29	$7,400
Rural Intersections	3,660	$42.82	$11,600
Rural Subtotal	**16,507 (96%)**	**$231,48 (94%)**	**$14,000**
Urban Projects			
Urban Segments	80	$7.24	$90,500
Urban Intersections	580	$6.56	$11,300
Urban Subtotal	**660 (4%)**	**$13.8 (6%)**	**$20,900**
Total	**17,167**	**$245.82**	**$14,300**

- Approximately 95% of the identified safety projects were at rural locations, compared to approximately 60% of severe crashes.
- The estimated cost to implement safety projects in rural locations is not exactly proportional to the distribution of severe crashes, but it is relatively close – approximately 80% of the cost of projects is directed toward road departure mitigation versus 76% of the crashes.
- The average implementation cost for rural projects is approximately 33% less than for the urban projects.

This data supports that the preparation of the County Roadway Safety Plans achieved the initial objectives – an average of $2.8 million of safety projects were identified for each county in Minnesota and the average implementation cost of $14,300 per project can reasonably be considered low-cost.

Wrap-Up and Lessons Learned

The look back at the entire process of developing the safety plans for Minnesota's counties identified a number of key points about the process itself and conclusions about the outcomes.

County Roadway Safety Plan Development and Technical Issues

- The commitment MnDOT made in the 2008 Strategic Highway Safety Plan to increasing the level of engagement by local highway agencies in this State's safety planning process was a critical decision that helped focus subsequent discussions and actions.
- MnDOT's decision to dedicate a fraction of the HSIP to improvements on the local road system was also critical to supporting the effort to address safety on local roadways.
- MnDOT's decision to add a systemic component (risk based as opposed to exclusive reliance on crashes) to the HSIP was the key to implementation of safety projects on local roadways. Initial expectations (subsequently proved by the analysis conducted during the development of the plans) were that there would be too few high crash locations on local roadways to continue using only the traditional site analysis approach to identifying candidates for safety investment.
- MnDOT's outreach to local agencies regarding safety was an important part of the process to generate participation by the local agencies and prepare the plans. This outreach was also instrumental in increasing the credibility of the effort and securing the support by the local agencies.
- Initial efforts at encouraging local agencies to participate in the HSIP by dedicating funding for improvements on local roadways was found to be a necessary component of securing local agencies participation in the statewide safety planning process, but it was not sufficient. Most of the counties simply do not have professional staff with the sufficient experience and training to conduct the necessary technical analyses to identify safety deficiencies and high priority safety projects. Providing technical support to the counties to conduct the system wide risk assessments and identify safety projects was found to be the best way of helping the counties get to implementation. It is clear that left on their own, virtually none of the counties would have been able to replicate the results achieved by the County Roadway Safety Plan project.
- Specific types of assistance that appears to be critical in helping counties get to implementation include:
  - Each County Roadway Safety Plan documents a prioritized list of county facilities; segments, curves and intersections based on the system wide risk assessment.
  - Each County Roadway Safety Plan describes suggested safety projects with the HSIP solicitation form already completed and ready to be submitted to MnDOT for potential HSIP funding.
  - MnDOT's initiative to help with federally required environmental documentation; exemptions for some types of projects and statewide categorical exclusions for other low-cost projects (lines and signs).
- After completing the analysis and plan development, a review was completed to verify the project finding. The review indicates that the County Roadway Safety Plan project achieved the initial objectives, specifically:
  - Priority crash types on county roadways were identified.

- A short list of highly effective and primarily low-cost safety strategies was identified.
- A system wide risk assessment using crashes and a variety of surrogates – roadway and traffic characteristics – was completed to identify and prioritize at-risk facilities.
- The review demonstrated that in every case the presence of the adopted risk factors was associated with a higher crash density and that the crash density across the entire county system increased with the presence of additional risk factors.
- The County Roadway Safety Plans identified over $245 million of suggested safety projects, an average of approximately $2.8 million per county.

- The review of the crash data identified an interesting and possibly useful relationship between infrastructure-based risk factors and driver-behavior crashes. High priority rural corridors at-risk for severe road departure crashes and urban corridors at risk for right-angle crashes at intersections were also found to be more at-risk for a variety of severe driver-behavior crashes. This relationship could support a more effective deployment of law enforcement resources – targeting only a fraction of a counties system instead of spreading the effort over all segments and intersections.
- Some previously published safety research suggests that severe crashes on rural roadways are randomly distributed. The results of the County Roadway Safety Plan process supports the notion that these severe crashes are widely distributed (a very low density of severe crashes per mile, curve and intersection) but the documented relationship between the risk factors and crash density supports a conclusion that these crashes are not as random as previously thought and that the use of certain roadway and traffic characteristics can in fact identify the locations that are more at-risk for particular types of severe crashes.

Project Management Issues

A senior engineer at CH2M HILL not associated with the County Roadway Safety Plan project was assigned the task of interviewing members of the Team to document feedback about their observations relating to work effort, organization, and process. Important comments include:

- Team and Staffing
    - Staff levels throughout the project were sufficient to deliver products on schedule. Initial estimates of staffing requirements proved to be accurate. During heavier workloads, a bullpen of available professionals in offices around the country was available and the additional staff helped with delivery.
    - The training that was provided at the beginning of each phase helped achieve a common understanding of procedures, deliverables, and schedule. The training also provided the opportunity to inform team members of changes that occurred in the analytical process after considering what parts of the previous phase could have been done better.
- Technology
    - MnCMAT was a very powerful tool and was well used by the analysts.
    - The video-logs provided by MnDOT were a critical part of the analytical process; allowing the analysts to conduct a virtual tour of each counties roadway facilities. If these video-logs had not been available, additional resources would have been required to take photographs along the county system or the quality of the analytical effort would have been compromised.

- The use of Excel spreadsheets for recording and combining data worked very well, was innovative, and macros were time savers for analysts. Spreadsheet tools were built especially for the project to compile and prioritize data with the use of automation. Analysts continuously suggested and improvements to the spreadsheets were made throughout the project.
- GIS was underutilized from the beginning. Not using GIS initially resulted in a variety of mapping problems that had to be addressed during the Phase V cleanup effort.
- The development and use of crash trees was considered to be innovative and very useful in helping frame a message about priority crash types and facilities.
- More effort should have been given to integrating the infrastructure and driver behavior messages.

▸ Quality

- Initially, not enough effort was assigned to managing quality of the deliverables. This was at least partly due to the fact that no one on the Team had every delivered a project as large or as complex as the County Roadway Safety Plan. However, as quality problems were identified, the Team developed solutions – PE Services was assigned the added task of making sure that the crash data cited in each Plan was in fact for that particular county, a spreadsheet of data for each county was developed by each analyst to be used as a common source and the data was double checked by a different analyst before being used in the plans, a comment log was developed to document changes to each county plan as a result of the review process with the county engineers, a final review by a technical editor was added to the plan development process to make the plans more reader friendly. As a result, the quality of the deliverables improved in each phase and there were far fewer errors reported in the county's Plans.
- Not enough emphasis or guidance was initially placed on the need for uniform and consistent spreadsheets developed by the various analysts. As a result, data was initially collected and recorded in a variety of ways. Standard formats for spreadsheets were improved as the project progressed; including more guidance was provided. A final clean-up was conducted as part of Phase V.
- Initial budget estimates were very accurate for all of the "normal" rural counties and for the first two phases, plans were being delivered on budget. However, the project eventually ran into two very unusual rural counties – Itasca and St. Louis and the Metropolitan counties (each three to ten times as many intersections and more miles of county roadway). It was fortunate that the team encountered the unusual counties several years into the project because enough information had been accumulated to be able to correlate level of effort with the number of intersections and miles of roadway that had to be analyzed. This allowed an estimate of the additional effort required in these unusual counties and their plans were then delivered within the newly established budgets.
- The initial estimate of completing each phase of the project in nine months was reasonable but in order to achieve this level of efficiency, two substantial changes were made in the approach. Phase I relied on the county engineers to identify their segments and intersections and the outcome was poor. The county engineers were not fully informed of the project's needs and expectations and some county engineers could not prepare this material in a reasonable time frame. As a result, team members began preparing this material and then sending it to the county engineers for review. This reduced the amount of time needed to assemble basic information needed by the analysts. Secondly, instead of having Phase II follow the completion

of Phase I, work was done concurrently. While each phase was being wrapped up, work began on assembling the basic data for the next phase. Eventually, the project schedule had to be extended by several months but this was primarily caused by the state shut-down in July, 2012 and the that the Metropolitan counties in Phase IV took more time to deal with their larger systems and requests for additional face-to-face meetings with their staff.